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Editorial Preface

From the Desk of Managing Editor…

"The question of whether computers can think is like the question of whether submarines can swim." ― Edsger W. Dijkstra, the quote explains the power of Artificial Intelligence in computers with the changing landscape. The renaissance stimulated by the field of Artificial Intelligence is generating multiple formats and channels of creativity and innovation.

This journal is a special track on Artificial Intelligence by The Science and Information Organization and aims to be a leading forum for engineers, researchers and practitioners throughout the world.

The journal reports results achieved; proposals for new ways of looking at AI problems and include demonstrations of effectiveness. Papers describing existing technologies or algorithms integrating multiple systems are welcomed. IJARAI also invites papers on real life applications, which should describe the current scenarios, proposed solution, emphasize its novelty, and present an in-depth evaluation of the AI techniques being exploited. IJARAI focusses on quality and relevance in its publications.

In addition, IJARAI recognizes the importance of international influences on Artificial Intelligence and seeks international input in all aspects of the journal, including content, authorship of papers, readership, paper reviewers, and Editorial Board membership.

The success of authors and the journal is interdependent. While the Journal is in its initial phase, it is not only the Editor whose work is crucial to producing the journal. The editorial board members , the peer reviewers, scholars around the world who assess submissions, students, and institutions who generously give their expertise in factors small and large— their constant encouragement has helped a lot in the progress of the journal and shall help in future to earn credibility amongst all the reader members.

I add a personal thanks to the whole team that has catalysed so much, and I wish everyone who has been connected with the Journal the very best for the future.

Thank you for Sharing Wisdom!

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CONTENTS

Adaptive Group Organization Cooperative Evolutionary Algorithm for TSK-type Neural Fuzzy Networks Design

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***Abstract*—This paper proposes a novel adaptive group organization cooperative evolutionary algorithm (AGOCEA) for TSK-type neural fuzzy networks design. The proposed AGOCEA uses group-based cooperative evolutionary algorithm and self-organizing technique to automatically design neural fuzzy networks. The group-based evolutionary divided populations to several groups and each group can evolve itself. In the proposed self-organizing technique, it can automatically determine the parameters of the neural fuzzy networks, and therefore some critical parameters have no need to be assigned in advance. The simulation results are shown the better performance of the proposed algorithm than the other learning algorithms.**

Keywords—TSK-type Neural Fuzzy Networks; Evolutionary Algorithm; Group based Symbiotic; Self Organization; System Identification

I. INTRODUCTION

In the field of artificial intelligence, neural fuzzy network [1-3] refers to combinations of neural networks and fuzzy logic. Because the advantages of neural fuzzy networks are powerful computation ability and human-like reasoning ability from neural networks and fuzzy systems, respectively, it has good performance for solving complex nonlinear problems. The neural fuzzy networks can perform the nonlinear mapping once the system parameters are trained based on a sequence of input and desired response pairs, and it does not require mathematical descriptions of system. Therefore, the determination of parameters is a critical issue for neural fuzzy networks.

The backpropagation (BP) [4, 5] is a common method and widely used for training neural fuzzy networks. It is well known that BP is an approximate steepest descent algorithm. The steepest descent algorithm is the simplest, and the minimization method. The advantage of steepest decent algorithm is very simple, requiring calculation only of the gradient, the disadvantage of steepest descent algorithm is that training time is generally longer than other algorithms; based on initial weight values, it is often to find the local optimal solution but not global optimal solution. Besides, BP training performance depends on the initial values of the system parameters, and for different network topologies one has to derive new mathematical expressions for each network layer.

Considering the aforementioned disadvantages one may be faced with suboptimal performance even for a suitable neural fuzzy network topology. Hence, the capability of training parameters and finding the global solution while optimizing the overall structure are important. The evolutionary methods using for training the fuzzy model has become a popular research field [6-20] because evolutionary methods simultaneously evaluate many points in the search space and are more likely to converge toward the global solution. The evolutionary fuzzy model is a learning process to generate a fuzzy model automatically by incorporating evolutionary learning procedures.

Recently, several improved evolutionary algorithms have been proposed [16-22].In [16], Bandyopadhyay et al. used the variable-length genetic algorithm (VGA) that allows the differentia of lengths of chromosomes in a population. Carse et. al. [17] used the genetic algorithm to evolve fuzzy rule based controllers. In [18], Chen proposed an efficient immune symbiotic evolution learning algorithm for compensatory neuro-fuzzy controller. In [19], Lin presented a novel self-constructing evolutionary algorithm to design a TSK-type fuzzy model. In [20], the group-based symbiotic evolution (GSE) was proposed to solve the issue of the traditional genetic algorithm that all the fuzzy rules were encoded into one chromosome. In [21], Lin proposed a hybrid evolutionary learning algorithm to combine the compact genetic algorithm and the modified variable-length genetic algorithm to perform structure/parameter learning to construct a network dynamically. Hsu [22] proposed a multi-groups cooperation-based symbiotic evolution (MGCSE) to train a TSK-type neural fuzzy network (TNFN). Their results showed that MGCSE can obtain better performance and convergence than symbiotic evolution. Although MGCSE being a good approach for training a TNFN, there is no systematic way to determine suitable groups for selecting chromosomes.

Although the above evolution learning algorithms [16-22] can improve the traditional genetic algorithms, these algorithms may encounter one or more of the following issues: 1) all fuzzy rules represent one chromosome; 2) the random group selection of fuzzy rules; 3) the numbers of fuzzy rules and group numbers have to be assigned in advance.

Recently, the data mining approach has been widespread used in several fields [23-30]. The data mining can be regarded as a new way of data analysis. One goal of data mining is to find association rules among frequent item sets in transactions. In [23], the authors proposed a mining method of ascertain

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large item sets to find association rules in transactions. Han et al. [24] proposed the frequent pattern growth (FP-Growth) to mine frequent patterns without candidate generation. Wu et al. [30] proposed a data mining method based on the genetic algorithm that efficiently improve the Traditional genetic algorithm by using analysis support and confidence parameters.

In order to solve aforementioned problems, this paper proposes an adaptive group organization cooperative evolutionary algorithm (AGOCEA) for designing a TSK-type neural fuzzy network. The AGOCEA adopts the group symbiotic evolution (GSE). Each population in the GSE is divided to several groups and each group represents a set of the chromosome that belongs to one single fuzzy rule. To solve the problem of random group selection, a data mining based group selection method was used to select the better groups. The adaptive group organization was used to solve the some parameters have to be assigned in advance.

This paper is organized as follows. In the Section II, a brief description of TSK-type neural fuzzy network is introduced. The proposed AGOCEA is described in the Section III. In the Section IV, the simulation results are presented. The conclusions are summarized in the Section V.

II. THE CONCEPT OF THE TSK-TYPE NEURAL FUZZY NETWORKS

A Takagi-Sugeno-Kang (TSK) type neural fuzzy network (TNFN) [1] employs different implication and aggregation methods from the standard Mamdani fuzzy model[3]. Instead of using fuzzy sets the conclusion part of a rule, is a linear combination of the crisp inputs. The fuzzy rule of TSK-type neural fuzzy network is shown as following equation:

IF x_1 is $A_{1j}(m_{1j}, \sigma_{1j})$ and x_2 is $A_{2j}(m_{2j}, \sigma_{2j})$ and … and x_n is $A_{nj}(m_{nj}, \sigma_{nj})$

THEN $y=w_{0j}+w_{1j}x_1+\ldots+w_{nj}x_n$. (1)

where n is the number of the input dimensions and j is the number of the fuzzy rules.

The structure of the TSK-type neural fuzzy network is shown in Fig. 1. It is a five-layer network structure. The functions of the nodes in each layer are described as follows:

Layer 1 (Input Node): No function is performed in this layer. The node only transmits input values to layer 2. That is

$$u_i^{(1)} = x_i . \quad (2)$$

Layer 2 (Membership Function Node): Nodes in this layer correspond to one linguistic label of the input variables in layer 1; that is, the membership value specifying the degree to which an input value belongs to a fuzzy set is calculated in this layer. For an external input x_i, the following Gaussian membership function is used:

$$u_{ij}^{(2)} = \exp\left(-\frac{\left[u_i^{(1)} - m_{ij}\right]^2}{\sigma_{ij}^2}\right), \quad (3)$$

where m_{ij} and σ_{ij} are, respectively, the center and the width of the Gaussian membership function of the jth term of the ith input variable x_i.

Layer 3 (Rule Node): The output of each node in this layer is determined by the fuzzy AND operation. Here, the product operation is utilized to determine the firing strength of each rule.

The function of each rule is

$$u_j^{(3)} = \prod_i u_{ij}^{(2)} = \prod_i \exp\left(-\frac{\left[u_i^{(1)} - m_{ij}\right]^2}{\sigma_{ij}^2}\right). \quad (4)$$

Layer 4 (Consequent Node): Nodes in this layer are called consequent nodes.

The input to a node in layer 4 is the output delivered from layer 3, and the other inputs are the input variables from layer 1 as depicted in Fig. 1.

$$u_j^{(4)} = u_j^{(3)}(w_{0j} + \sum_{i=1}^{n} w_{ij}x_i), \quad (5)$$

where the summation is over all the inputs and where w_{ij} are the corresponding parameters of the consequent part.

Layer 5 (Output Node): Each node in this layer corresponds to one output variable. The node integrates all the actions recommended by layers 3 and 4 and acts as a defuzzifier with

$$y = u^{(5)} = \frac{\sum_{j=1}^{M_k} u_j^{(4)}}{\sum_{j=1}^{M_k} u_j^{(3)}} = \frac{\sum_{j=1}^{M_k} u_j^{(3)}(w_{0j} + \sum_{i=1}^{M_k} w_{ij}x_i)}{\sum_{j=1}^{M_k} u_j^{(3)}}, \quad (6)$$

where M_k is the number of fuzzy rule.

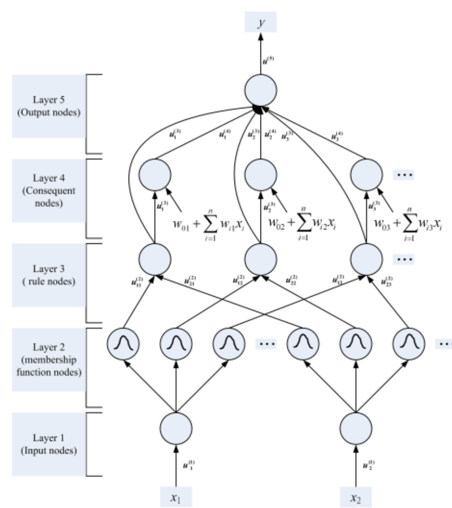

Fig. 1. Structure of TSK-type neural fuzzy network.

III. ADAPTIVE GROUP ORGANIZATION COOPERATIVE EVOLUTIONARY ALGORITHM

The flowchart of the proposed adaptive group organization cooperative evolutionary algorithm (AGOCEA) is shown in Fig. 2. The structure of chromosomes to construct a TNFN is shown in Fig. 3. The coding structure of chromosomes is shown in Fig. 4.

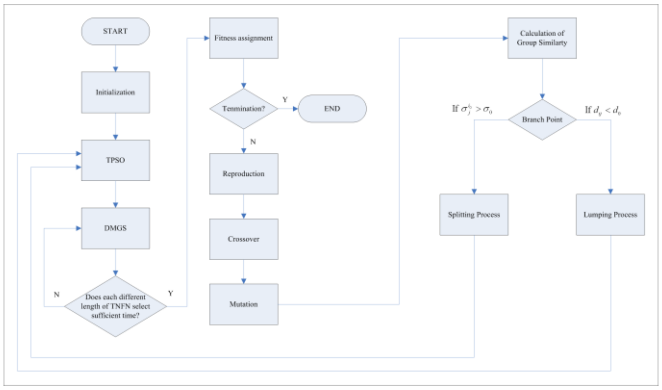

Fig. 2. The flowchart of the AGOCEA.

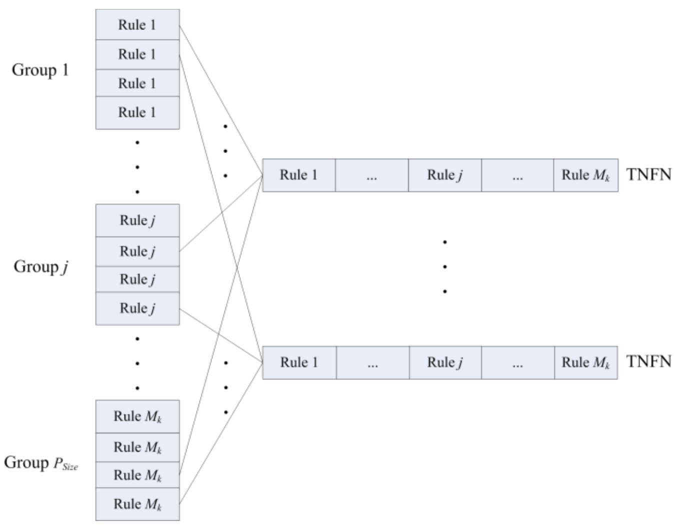

Fig. 3. The structure of the chromosome in the AGOCEA.

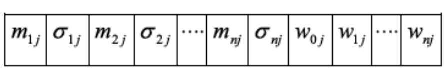

Fig. 4. The structure of the chromosome in the AGOCEA.

The learning process of the AGOCEA involves ten operators: initialization, two phase self organization, data mining based group selection, fitness assignment, reproduction, crossover, mutation, calculation of group similarity, splitting process, and lumping process. The whole learning process is described step-by-step as follows:

A. Initialization

Before the AGOCEA is designed, individuals forming several initial groups should be generated. The initial groups of the AGOCEA are generated randomly within a fixed range. The following formulations show how to generate the initial chromosomes in each group:

Deviation: $Chr_{g,c}[p]=random[\sigma_{\min}, \sigma_{\max}]$ (7)

where p=2, 4,⋯, 2n; g=1, 2,⋯, M_k; c=1, 2,⋯, N_C,

Mean: $Chr_{g,c}[p]= random[m_{\min}, m_{\max}]$ (8)

where p=1, 3,⋯, 2n-1;

Weight: $Chr_{g,c}[p]= random[w_{\min}, w_{\max}]$ (9)

where p=2n+1, 2n+2,⋯, 2n+(n+1),

where $Chr_{g,c}$ represents cth chromosome in gth group; M_k represents k rules that used to form a TNFN and N_C is the total number of chromosomes in each group; p represents the pth gene in a $Chr_{g,c}$; and $[\sigma_{\min}, \sigma_{\max}]$, $[m_{\min}, m_{\max}]$, and $[w_{\min}, w_{\max}]$ represent the range that are predefined to generate the chromosomes.

B. Two phase self organization (TPSO)

After every group is initialized, the AGOCEA adopts pervious research which was TPSO [29, 31] to decide the suitable selection times of each number of rules (in this paper the number of rules lie between [$M_{\max}$, $M_{\min}$]); that is, it determines the selection times of M_k groups which form a TNFN with k rules.

After the TPSO, the selection times of the suitable number of rules in a TNFN will increase, and the selection times of the unsuitable number of rules will decrease. The details of the TPSO are listed as follows:

Step 0. Initialize the probability vectors:

$$V_{M_k}=0.5, \quad \text{where} \quad M_k=M_{\min}, M_{\min+1}, \cdots, M_{\max} \tag{11}$$

$$Accumulator = 0 \tag{12}$$

Step 1. Update the probability vectors according to the following equations:

$$\begin{cases} V_{M_k}=V_{M_k}+(Upt\_value_{M_k}*\lambda), & \text{if} \quad Avg \le fit_{M_k} \\ V_{M_k}=V_{M_k}-(Upt\_value_{M_k}*\lambda), & \text{otherwise} \end{cases} \tag{13}$$

$$Avg=\sum_{M_k=M_{\min}}^{M_{\max}} fit_{M_k} / (M_{\max}-M_{\min}+1) \tag{14}$$

$$Upt\_value_{M_k}=fit_{M_k} \Big/ \sum_{M_k=M_{\min}}^{M_{\max}} fit_{M_k} \tag{15}$$

$$\begin{aligned} &\text{if} \quad Fitness_{M_k} \ge (Best\_Fitness_{M_k} - ThresholdFitnessvalue) \\ &\text{then} \quad fit_{M_k}=fit_{M_k}+Fitness_{M_k} \end{aligned} \tag{16}$$

where V_{M_k} is the probability vector, λ is a predefine threshold value, *Avg* represents the average fitness value in the whole population, $Best\_Fitness_{M_k}$ represents the best fitness value with M_k rules, fit_{M_k} is the sum of fitness value of TNFN with M_k rules, $Fitness_{M_k}$ is the fitness value with M_k rules, *ThresholdFitnessvalue* is a predefined threshold value.

Step 2. Determine the selection times according to the probability vectors as follows:

$$R_{p_{M_k}} = (Selection\_Times) * (V_{M_k} / Total\_Velocy) \ , \tag{17}$$

$$Total\_Velocy = \sum_{M_k = V_{\min}}^{V_{\max}} V_{M_k} \ , \tag{18}$$

where *Selection_Times* represents total selection times in each generation, *Total_Velocy* is summation of the probability vectors V_{M_k}, $R_{p_{M_k}}$ is the selection times of M_k groups that use to select *k* chromosomes for constructing a TNFN.

Step 3. After step 2, the selection times of every numbers of rules in a TNFN are obtained. Then the $R_{p_{M_k}}$ times are used to select *k* chromosomes form M_k groups to construct a TNFN.

Step 4. In the proposed TPSO, for avoiding suitable M_k groups may fall in the local optima solution, the TPSO proposed two different actions to update the V_{M_k}. Decide the deferent action according to the following equations:

If *Accumulator* ≤ *TPSOTimes* (19)
Then do Step1, Step2, and Step 3,

If $Best\_Fitness_g$ = *Best_Fitness* (20)
Then *Accumulator* = *Accumulator* + 1,

If *Accumulator* > *TPSOTimes* (21)
Then do Step 0 and *Accumulator* = 0,

where *TPSOTimes* is a predefined value; $Best\_Fitness_g$ represents the best fitness value of the best combination of chromosomes in *g*th generation; *Best_Fitness* represents the best fitness value of the best combination of chromosomes in current generations. Eqs. (19)-(21) represents that if the fitness is not changed for a sufficient number of generations, the suitable M_k groups may fall in the local optima solution.

C. Data mining based group selection (DMGS)

After the TPSO step, the selection times of each rule number in a TNFN is decided. The AGOCEA then performs selection step. The selection step in the AGOCEA can be divided by selection of groups and chromosomes. In the selection of groups, this paper uses the DMGS to improve the random selection. In the DMGS, the groups are selected according to the frequent patterns found by FP-Growth. In the proposed DMGS, the FP-Growth finds the frequent groups from a transaction (in this paper a transaction means a set of the M_k group indexes that perform well). After the frequent group indexes have been found, the DMGS selects the M_k groups indexes according to the frequent group indexes. To avoid the frequently-occurring groups from falling in the local optimal solution, the DMGS uses three actions to select M_k groups. The three actions defined in this paper are normal, search, and explore. The detail of the DMGS is shown as follows:

Step 0. The transactions are building as follow equation:

$$\begin{aligned} &\text{if} \quad Fitness_{M_k} \geq Best\_Fitness_{M_k} - ThresholdFitnessvalue \\ &\text{then} \quad Transaction_j[i] = TNFNRuleSet_{M_k}[i] \\ &\text{where} \quad i = 1,\ 2, \cdots,\ M_k \\ &\qquad\quad j = 1,\ 2, \cdots,\ TransactionNum \end{aligned} \tag{22}$$

where the $Fitness_{M_k}$ represents the fitness value of TNFN with M_k rules, *TransactionNum* is the total number of transactions $Transaction_j[i]$ represents the *i*th item in the *j*th transaction, $TNFNRuleSet_{M_k}[i]$ represents *i*th group index in M_k group indexes that are selected to form a TNFN with M_k rules. For example, as shown in Table I, the first transaction of the transaction set means the 3 rules TNFN that select from 1st group, 4th group, and 8th group has a well performance.

TABLE I. TRANSACTIONS IN A FP-GROWTH.

Transaction index	Group indexes
1	1, 4, 8
2	2, 4, 7, 10
⋮	⋮
TransactionNum	1, 3, 4, 6, 8, 9

Step 1. Normal action:

After building up the transactions, the DMGS selects group according to different action types. If the action type is normal action, the DMGS selects the group as following equation:

$$\begin{aligned} &\text{if} \quad Accumulator \leq NormalTimes \\ &\text{then} \quad GroupIndex[i] = Random[1,\ P_{size}] \\ &\text{where} \quad i = 1,\ 2,\ \cdots,\ M_k; M_k = M_{\min},\ M_{\min+1}, \cdots,\ M_{\max}, \end{aligned} \tag{23}$$

where *Accumulator* is defined in Eq. (20); *GroupIndex*[*i*] represents selected *i*th group index of the M_k group indexes and P_{size} represents there are P_{size} groups in a population in the AGOCEA.

Step 2. Find the frequent groups:

If the action is searching or exploring action, the DMGS uses the FP-Growth [24] to find frequent group indexes in transactions. The frequent group indexes are found according to the predefined *Minimum_Support*. The *Minimum_Support* means the minimum fraction of transactions that contain an item set. The FP-Growth algorithm can be viewed as two parts: construction of the FP-tree and FP-growth. The sample transactions shown in Table II are taken as examples. *Minimum_Support* = 3 is considered in this example. Frequent group indexes generated by FP-growth shown in Table III are then thrown into the pool that's named *FrequentPool*.

TABLE II. SAMPLE TRANSACTIONS.

Transaction index	Group indexes
1	{b, c, e, f, g, h, p}
2	{a, b, c, f, i, m, o}
3	{c, f, i, m, o}
4	{b, c, e, s, p}
5	{a, b, c, d, f, m, o}

TABLE III. FREQUENT GROUP INDEXES GENERATED BY FP-GROWTH WITH *MINIMUM_SUPPORT* = 3.

Suffix group	Cond. group base	Cond. FP-tree	Frequent group indexes
B	c:4	c:4	cb:4
F	cb:3, c:1	c:4, cb:3	cf:4, bf:3, cbf:3
M	cbf:2, cf:1	cf:3	cm:3, fm:3, cfm:3
O	cbfm:2, cfm:1	cfm:3	co:3, fo:3, mo:3, cfo:3, cmo:3, fmo:3, cfmo:3

Step 3. Select the group indexes according to different actions:

After obtaining the frequent item sets, the DMGS selected group indexes according to different actions that describe as follows:

In the searching action, the group indexes are selected from the frequent item as follow equations:

$$\text{if} \quad NormalTimes < Accumulator \leq SearchingTimes$$

$$\text{then} \quad GroupIndex[i] = w,$$

where

$$w = Random[1,\ P_{size}] \ \text{ and } \ w \in FrequentItemSet[q];$$

$$FrequentItemSet[q] = Random[FrequentPool];$$

$$q = 1,\ 2, \cdots,\ FrequentPoolNum;$$

$$i = 1,\ 2, \cdots,\ M_k; M_k = M_{\min},\ M_{\min+1}, \cdots,\ M_{\max}, \quad (24)$$

where *SearchingTimes* is a predefined value that judge to perform searching action; *FrequentPool* represents the sets of frequent item set that obtain from FP-Growth; *FrequentPoolNum* presents the total number of sets in *FrequentPool* and *FrequentItemSet*[*i*] presents a frequent item set that select from *FrequentPool* randomly. In Eq. (24), if M_k greater than the size of *FrequentItemSet*[*i*], the remaining groups are selected by Eq. (23).

In the exploring action, the group indexes are selected according to the frequent item as follow equations:

$$\text{if} \quad SearchingTimes < Accumulator \leq ExploringTimes$$

$$\text{then} \quad GroupIndex[i] = w,$$

where

$$w = Random[1, P_{size}] \ \text{ and } \ w \notin FrequentItemSet[i];$$

$$FrequentItemSet[i] = Random[FrequentPool];$$

$$i = 1,\ 2, \cdots,\ M_k; M_k = M_{\min},\ M_{\min+1}, \cdots,\ M_{\max}, \quad (25)$$

where *ExploringTimes* is a predefined value that judge to perform exploring action.

Step 4. After selecting M_k group indexes, the k chromosomes are selected from M_k group as follows:

$$ChromosomeIndex[i] = q,$$

$$\text{where} \quad q = Random[1,\ N_c]$$

$$i = 1,\ 2, \cdots,\ k \quad (26)$$

where N_c represents the number of chromosomes in each group; *ChromosomeIndex*[*i*] represents the index of a chromosome that select from *i*th group.

The illustration of the DMGS is shown in Fig. 5 with simple descriptions as follows: suppose the TPSO determines that 4 rules are expected, and 3 out of 7 groups, group 2, 3 and 6, are deemed as frequent groups. If the current action type of the DMGS is normal action, then 4 random groups will be selected to form a TFS. If the search action is taken, then frequent group 2, 3 and 6 will be selected. The remaining one group will be draw randomly from group 1, 4, 5 and 7. If the explore action is taken, then the 4 non-frequent group 1, 4, 5 and 7 will be selected in case of the problem of local optimum.

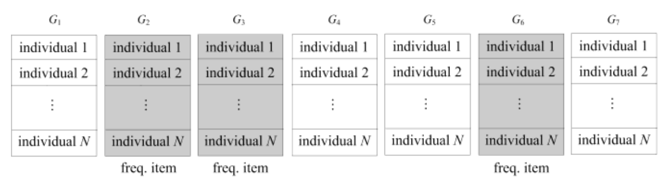

Fig. 5. The example of the DMGS.

D. Fitness assignment

The fitness value of a rule (an individual) is calculated by concatenating this individual with elites of other groups selected by DMGS. The details for assigning the fitness value are described as follows:

Denote G_1, G_2, …, G_{M_k}, the M_k groups selected by the DMGS; $G_j \cdot p_i$ denotes the *i*th individual of the *j*th group; y_j refers to the elite individual of the *j*th group. Then the fitness of the individual $G_j \cdot p_i$ can be computed as follows:

$$fitness(G_j \cdot p_i) = fitness(G_1 \cdot y_1, \cdots, G_j \cdot p_i, G_{j+1} \cdot y_{j+1}, \cdots, G_{M_k} \cdot y_{M_k}) \quad (27)$$

E. Reproduction

To perform reproduction, elite-based reproduction strategy (ERS) [22] is adopted in this study. In ERS, every chromosome in the best combination of Mk groups must be kept by performing reproduction step. In the remaining chromosomes in each group, the roulette-wheel selection method [32] is adopted for proceeding with the reproduction process.

Then the well-performed chromosomes in the top half of each group [14] proceed to the next generation. The other half is generated by performing crossover and mutation operations on chromosomes in the top half of the parent individuals.

F. Crossover

In this step, a two-point crossover strategy [32] is adopted. Once the crossover points are selected, exchanging the site's values between the selected sites of individual parents can create new individuals. These individuals are offspring which inherent the parents' merits.

G. Mutation

The utility of the mutation step can provide some new information to every group at the site of an individual by randomly altering the allele of a gene.

Thus mutation can lead to search new space which can avoid falling into the local minimal solution. In the mutation step, uniform mutation [33] is adopted, and the mutated gene is drawn randomly from the domain of the corresponding variable.

H. Calculation of group similarty

In order to achieve self adaptive group organization, it must determine the group similarity first. This paper involves the three measurements to determine the group similarity: 1. group centers, 2. group distance, and 3. group standard deviation.

Group centers: $$\mathbf{y}_j = \frac{1}{m_j}\sum_{i=1}^{m_j}\mathbf{x}_{l_{ij}},\ j = 1, 2, \cdots, N_C \quad (28)$$

Group distance: $$d_{ij} = \left\|\mathbf{y}_i - \mathbf{y}_j\right\| = \sqrt{\sum_{i=1,\,j=1}^{P_{size}}\left(\mathbf{y}_i - \mathbf{y}_j\right)^2} \quad (29)$$

Group standard deviation: $$\sigma_j^{(i)} = \sqrt{\frac{1}{m_j}\sum_{p=1}^{m_j}\left(x_{l_{pj}}^{(i)} - y_j^{(i)}\right)^2} \quad (30)$$

$$\sigma_j^{(i_0)} = \max_{i=1,\cdots,n}\sigma_j^{(i)}$$

where $\mathbf{y}_j$ is the center of the *j*th group, m_j is the total number of *j*th group, $\mathbf{x}_{l_{ij}}$ is *i*th chromosome in the *j*th group, d_{ij} is the Euclidean distance between the *i*th group and *j*th group, $\sigma_j^{(i)}$ is the *i*th bit standard deviation in the *j*th group, $\sigma_j^{(i_0)}$ is the largest standard deviation of *j*th group.

After calculating above three measurements, it will be used to adjust the group organization of the neural fuzzy network by following two processes: splitting process and lumping process.

I. Splitting process

If $\sigma_j^{(i_0)} > \sigma_0$, where σ_0 is standard deviation splitting threshold, it means the chromosomes in the jth group are very dissimilar, so the AGOCEA will call Splitting process.

The Splitting process will divide jth group into two groups, which are j+ group and j- group, by following step: the top 50% (fitness value) chromosomes in the *j*th group will put into *j*+ group, the other 50% chromosomes in the *j*th group will put into *j*- group. The other 50% in the *j*+ group and *j*- group will generate randomly. After Splitting process, the dissimilar group will be separated into different groups, and total number of group will increase.

3.10 Lumping process

If $d_{ij} < d_0$, where d_0 is lumping threshold, it means the chromosomes are very similar between *i*th group and *j*th group, so the AGOCEA will call Lumping process. The Lumping process will merge *i*th group and *j*th group into a new group. The new group consists of the top 50% chromosomes from *i*th group and the top 50% chromosomes from *j*th group. After Lumping process, the similar groups will be merged into a new group, and total number of group will decrease.

IV. Simulation Results

The example used for identification of nonlinear dynamic system given by Narendra and Parthasarathy [34] is described as following difference equation:

$$y(k+1) = \frac{y(k)}{1+y^2(k)} + u^3(k) \quad (31)$$

The output of above equation depends nonlinearly on both its past value and the input, but the effects of the input and output values are not additive. The training input patterns are random value in the interval [-2, 2]. To determine the performance of the algorithms, this example adopts the root mean square error (RMSE). The definition of the RMSE is:

$$\text{RMSE} = \sqrt{\frac{\sum_{k=1}^{N}\left(\hat{y}(k) - y(k)\right)^2}{N}} \quad (32)$$

where $\hat{y}(k)$ is desired output, $y(k)$ is model output, and N is number of data.

In order to determine performance of the difference learning algorithm, this example is compared AGOCEA with HESP [35], ESP [36], MCGSE [22], SANE [37], and GA [6]. All algorithms were learned for 500 generations and repeated for 50 trails. The initial parameters of the AGOCEA are given in Table IV. Figure 6-11 show the output of all algorithms for the input signal $u(k) = \sin\left(\frac{2\pi k}{25}\right)$.

In these figures, the symbol "o" represents the desired output of the nonlinear dynamic system, and the symbol "*" represents the output of all algorithms. It can be seen from the Fig. 5-10 that the model output of AGOCEA has more accuracy than the other comparing learning algorithms.

TABLE IV. INITIAL PARAMETERS OF THE AGOCEA.

Parameters	Value
P_{size}	30
N_c	20
Selection_Times	40
NormalTimes	10
Searching Times	20
ExploringTimes	30
Crossover Rate	0.6
Mutation Rate	0.3
$[M_{min}, M_{max}]$	[5, 15]
$[m_{min}, m_{max}]$	[-10, 10]
$[\sigma_{min}, \sigma_{max}]$	[1,15]
$[w_{min}, w_{max}]$	[-10, 10]
σ_0	6
d_0	12

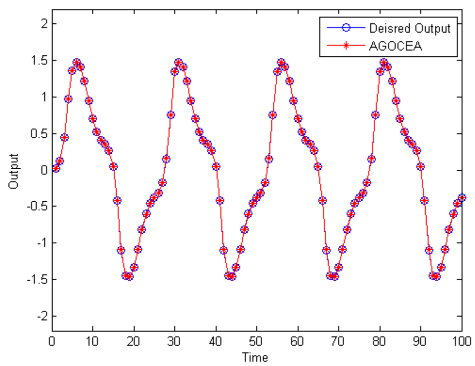

Fig. 6. Identification Results Of The Desired Output And The AGOCEA.

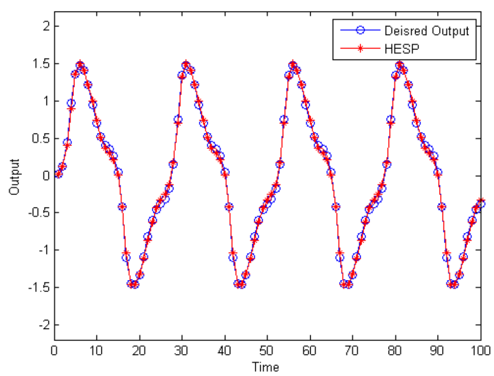

Fig. 7. Figure 4.2 Identification Results Of The Desired Output And The HESP.

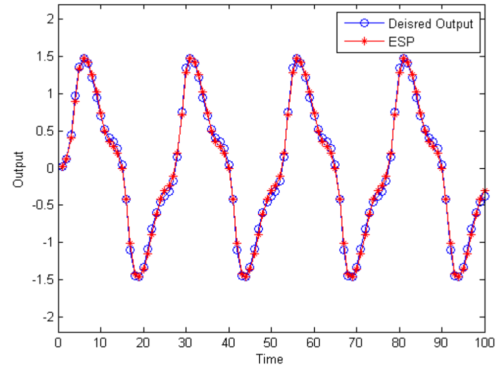

Fig. 8. Identification Results Of The Desired Output And The ESP.

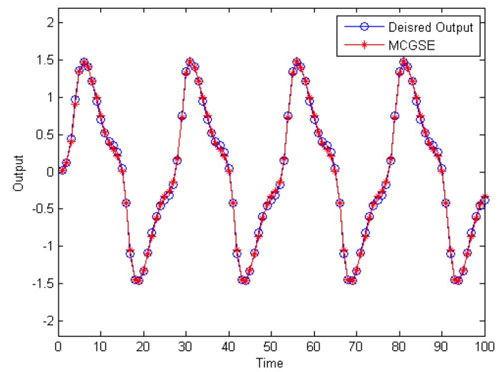

Fig. 9. Identification Results Of The Desired Output And The MCGSE.

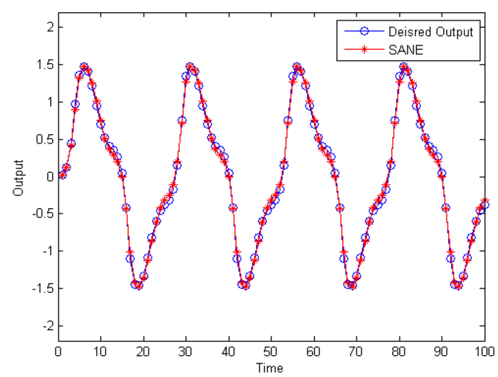

Fig. 10. Identification Results Of The Desired Output And The SANE.

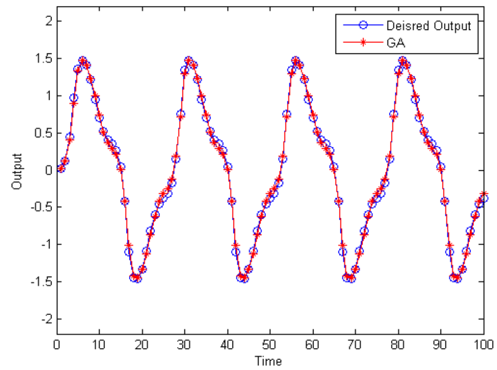

Fig. 11. dentification Results Of The Desired Output And The GA.

Figure 12 (a)-(f) show the identification error between the desired output and all algorithms' output. As shown in Fig. 12 (a)-(f), the AGOCEA illustrated the smaller error than other algorithms. Figure 13 provides the learning curve of the various learning algorithms, it can be seen from the learning curve that the AGOCEA converge faster and better than the other learning algorithms.

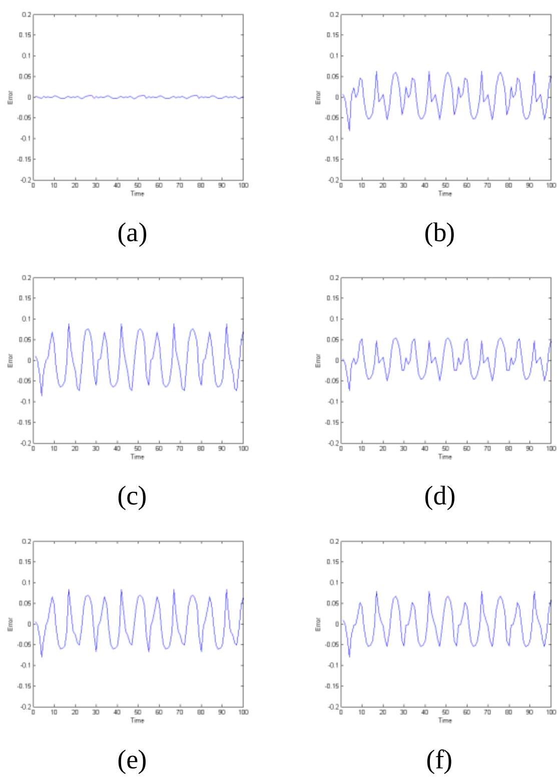

Fig. 12. Identification Errors Of The (A) AGOCEA, (B) HESP, (C) ESP (D) MCGSE, (E) SANE, And (F) GA.

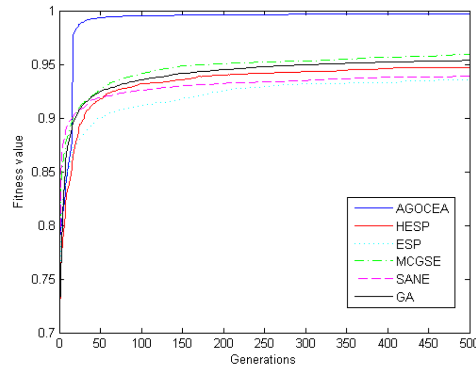

Fig. 13. The Learning Curve Of AGOCEA, HESP, ESP, MCGSE, SANE, And GA.

Table V shows the results obtained from a RMSE analysis of the various learning algorithms. There was a significant difference between the proposed AGOCEA and the other learning algorithms. No matter which performance index is, the proposed AGOCEA has the better performance than the other learning algorithms.

TABLE V. RMSE COMPARISON OF VARIOUS LEARNING ALGORITHMS.

Algorithm	RMSE			
	Mean	Best	Worst	STD
AGOCEA	**0.0023**	**0.0011**	**0.0034**	**0.0006**
HESP	0.0417	0.0285	0.0584	0.0071
ESP	0.0527	0.0342	0.0744	0.0112
MCGSE	0.0326	0.0228	0.0625	0.0062
SANE	0.0501	0.0274	0.0765	0.0117
GA	0.0470	0.0257	0.1117	0.0212

V. CONCLUSIONS

In this paper, the AGOCEA is proposed for designing TSK-type neural fuzzy network. The proposed AGOCEA not only determine the suitable number of fuzzy rules and group number but also efficiently tune the free parameters in the TNFN. The AGOCEA adopts the GSE that each population is divided to several groups and each group represents only one fuzzy rule. In order to solve the problem of random group selection, a data mining based group selection method was used to select the better groups. Furthermore, the adaptive group organization was proposed to solve the some parameters have to be assigned in advance. The simulation results show that the AGOCEA trained TNFN is superior to other methods. Although the proposed AGOCEA can obtain better results in comparison with the other learning algorithms, it still has a limitation. The important limitation lies in the fact that the proposed AGOCEA emphasize the network parameter learning and the group structure organization, it is a two level learning structure. While the problems become more complex, there is possible that increase the levels of learning structure.

Further research might explore how to determine the suitable levels of the learning structure for dealing with more complex problems.

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Color Radiomap Interpolation for Efficient Fingerprint WiFi-based Indoor Location Estimation

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***Abstract*— Indoor location estimation system based on existing 802.11 signal strength is becoming increasingly prevalent in the area of mobility and ubiquity. The user-based location determination system utilizes the information of the Signal Strength (SS) received from the surrounding Access Points (APs) to determine the user position. In this paper, we focus on the development of a user position estimation using existing WiFi environment for its low cost and ease of deployment and study fingerprint-based deterministic techniques for their simplicity and effectiveness. We present the color radio map interpolation method with ease to development, reduce the calibration effort on creating radio map while still retain the accuracy of user position estimation. The average accuracy error 1.108 meter is achieved on 1.25 meter x 2.5 meter of cell grid size.**

Keywords—network; indoor localization; radio map; user monitoring, location estimation

I. Introduction

In the era of ubiquitous computation, location-aware system becoming increasingly popular as well as practical. Knowing the locations of a device and the user inside a building is a necessary prerequisite for location-based services. Location estimation systems can be classified regarding various parameters: indoor or outdoor, hardware dependent or independent, deterministic or probabilistic based on the technique, WiFi, Bluetooth, infrared, ultrasound, and ultra-wideband depending on the technology. One promising approach to measuring location is triangulation from 802.11 signal strength on wireless devices. Given radio signal strength measurements on the client from a few different access points, researchers have shown how to compute location down to a few meters. This type of location measurement is especially attractive because it only uses the buildings and users existing devices. We can use existing wireless network in a building that communicate with users mobile phone devices. This system works properly in indoors where GPS and mobile phone location is not working.

However, the accuracy of such systems usually depends on a meticulous calibration procedure that consists of physically moving a wireless client to many different known locations, and sometimes orientations, inside a building. It may be unrealistic to expect anyone to spend the resources on such work. When presented with this prospect as part of a new product, software product planners sometimes balk, complaining that system administrators are reluctant to keep the locations of printers updated, much less create and maintain a high-resolution table of 802.11 signal strengths.

One alternative to manual calibration is to analytically predict signal strengths based on a real physical simulation of the building and radio frequency propagation. There is a work on predicting signal strengths for wireless networking [1][2], but mostly aimed as a guide to the placement of access points and not location measurement. Bahl and Padmanabhan's RADAR [3] system was one of the first and most comprehensive studies of 802.11 location, and they considered the question of physical simulation versus manual calibration of signal strengths. They discovered that physically simulating signal strengths increased their median location error by about 46% (from 2.94 meters to 4.3 meters) over manual calibration. Moreover, a good physical simulation usually requires a more detailed model of the building than is normally available.

Many researchers try to find the best method to overcome the problem of calibration effort. They try to reduce the number of sample or physical area and interpolate to determine the value on that blank spot area [4][5]. This is more difficult with most other 802.11 location algorithms which instead must classify signal strengths into only previously seen locations. As expected, the accuracy goes down with reduced calibration data, so they should make tradeoff between accuracy and effort. In this paper, we focus on how to significantly reduce the offline calibration effort while still achieving high accuracy in location estimation with effective visualization capabilities. We proposed a color based *radiomap* interpolation where the interpolation is made by using color representative of signal strength information. The proposed system based on fingerprint radio map with initial cell grid size that improved with gradually color interpolation. Empirical experiment show that proposed system gain the high accuracy while improved the radio map grid size with color interpolation that reduce the effort on offline calibration.

II. Indoor Location Estimation Based on WIFI Signal Strength

A. Positioning Techniques

Bose and Heng [6] classified WiFi-based positioning methods into Cell Identity (Cell-ID), Time of Arrival (TOA), Time Difference of Arrival (TDOA), Angle of Arrival (AOA), and signal strength categories.

Cell Identity (Cell-ID) is a basic wireless positioning system solution. It matches the target's position with its connection to an Access Point (AP). It does not require complex operations such as time synchronization and multiple APs. Time of Arrival (TOA) measures a distance using the travel time of a radio signal from a transmitter to a receiver. Its application requires time synchronization of the transmitter and receiver, which is difficult to achieve for close ranges. To overcome the problem, Time Difference of Arrival (TDOA) was developed, which utilizes the time difference between the receiver and two or more receivers. That is to say, whereas TOA requires time synchronization of transmitters and receivers, TDOA needs just synchronization between receivers. Angle of Arrival (AOA) determines the position of a receiver by measuring the angle to it from a transmitter. An AP must use smart antennas and be capable of mounting them under static conditions.

Signal Strength based technique uses the signal attenuation property of the radio wave *Received Signal Strength Indication* (RSSI) to measure the distance from a receiver to transmitter using the distance-to-signal-strength relationship. One common approach of RSSI-based system is fingerprint approach that consists two phases: a *training phase* and a *tracking phase*. In the training phase, the received signal strength information is filtered, interpolated, and eventually stored in a database as sample points. In the tracking phase, the position is determined by comparison with the received signal strength sample points stored in the database [10]. The accuracy of this system is a function of the sample points' sampling space, an estimation method and the structure of the database. However, such a method requires the time consuming on survey procedure or calibration process.

B. Reducing Calibration Time

Reducing calibration time is one of the methods to decrease manual effort. In recent years, most research with high accuracy calibrate large amount of data on a fixed location. It normally requires tens or even hundreds of samples to stabilize signal strength distributions. With constant calibration frequency, the ratio between calibration samples and time is linear. Therefore, reducing calibration time to half of the origin means that only 50% of samples can be collected.

C. Linear Interpolation Method

Linear interpolation is a method of determining an unknown point between two known points. The unknown point (x, y), then could calculated from the two known points (x_o, y_o) and (x_1, y_1). Linear interpolation commonly is expressed in the form

$$y = y_o + (x-x_0) * (y_1-y_0) / (x_0 - x_0) \quad (1)$$

Also, this kind of interpolation on set of data points (x_0, y_0), (x_1, y_1), …, (x_n, y_n) can be defined as the concatenation of linear interpolations between point pairs. The result is in a continuous line. In the present study, the interpolation method was used to predict the signal strength of an unknown point between two known points after Kalman filtering process. First, the coordinates (x, y) of an unknown point between two points were obtained by interpolation. After that, the signal strength of the unknown point was calculated by interpolation.

III. COLOR RADIOMAP INTERPOLATION METHOD FOR REDUCING CALIBRATION EFFORT

A. System Architecture

In this research, a WiFi-based positioning system based on the fingerprint method was developed. As mentioned, the system is configured for two phases: *training* and *tracking*. The objective of the training phase is to build a signal information database, named *Color Radiomap* because we use color as representative of the radio signal. Received signal data were arranged in computer memory according to the IDs of APs. The signal data of the selected APs are then used in the signal processing step, involving filtering and interpolation, in order to reduce the noise effect. The signal data thus modified are stored in the database and converted into its color representative in cell based map or grid based map. In the tracking phase, the target's location is calculated by comparing the signal patterns stored in the signal database in the training phase. The calculated position of target then appears on the drawn system map in grid based position. Data processing is summarized in Fig. 1.

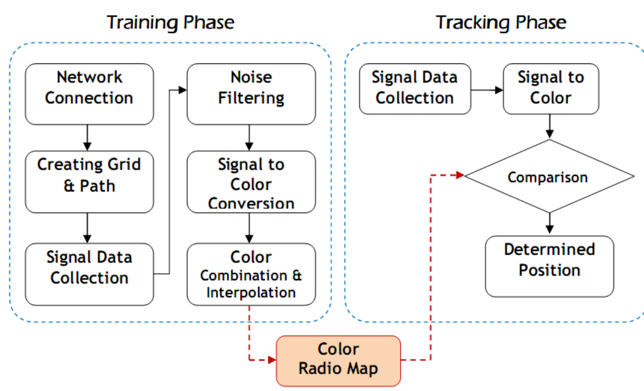


Fig. 1. Data Flow Of Indoor Location Estimation Fingerprint Method.

The data processing of each phase, in detail, is as follows.

(1) Training phase

The first step is to draw a two-dimensional map of the building for data collection and tracking. Based on the map, we create the grid in a rectangle shape and data gathering route is determined. Each route is stored as one path, and the collected signal data can be stored for each Access Point (AP) on each grid. Fig. 1 shows the procedures of the training phase. The signal strength information collected in the operation outlined above, needs to be processed for noise reduction as well as for the purposes of building a signal strength distribution model. The signal strength data collected from the APs is processed using an adaptive *Kalman* filtering algorithm to eliminate the noise and interference effects. In building the signal distribution model, interpolation is applied. The signal distribution at each point on the data gathering route is stored in the *Radiomap* database of the server computer.

(2) Tracking phase

In the tracking phase, signal data are processed in real-time by the filtering algorithm of the RSSI is compared with that stored in *Radiomap*. Based on this comparison, the optimal location is determined and marked on the map efficiently using color representative visualization approach.

B. Grid Segment

We present a Grid Segment Process to segmenting area in the building. The segment size is assumed in a tolerant distance where people can see other people clearly in that chosen distance. This assumption is used because we design our indoor location estimation system for using on disaster management for monitoring and finding people or user inside a hospital or group home in the normal situation or disaster situation. If we can determine the location of a user in the estimated grid position, this will enough to using such information by other people to finding or monitoring the user. Initial distance for grid size in this research is 5 meters. If the grid size with its error on an estimation is not accurate enough, we can extend the radio map into more detailed segment of the grid to achieve better accuracy. This can be done by using proposed color interpolation method explained in the next section. After creating grid segment layout for the building, then signal information is collected on each grid for each AP. We use median value from around 20 samples for each grid.

C. Color Representation for Color Radiomap

The received signal of each access point is converted into its color representative. This system uses 3 signals information from 3 different AP's based on triangulation approach. Each access point has its basic color that different each other. The three input AP (AP_1, AP_2, & AP_3) using base color *red*, *green* and *blue* color respectively. The color map is based on signal strength information recorded from signal data collection process. The gradation of color is based on the *HSL (Hue Saturation Luminance)* value where *Luminance* is a function of the signal strength. Assuming SS_{px} is a variable for signal strength (in percentage) for the position of x meter from the initial position. Then the color for the grid of x meter distance is measured by these formulas:

$$AP_1 \rightarrow RGB(255,0,0) \rightarrow HSL(0,240,f(L_x)) \qquad (2)$$

$$AP_2 \rightarrow RGB(0,255,0) \rightarrow HSL(80,240,f(L_x)) \qquad (3)$$

$$AP_3 \rightarrow RGB(0,0,255) \rightarrow HSL(160,240,f(L_x)) \qquad (4)$$

$$f(L_x) = 240 - (SS_{px} * 120) \qquad (5)$$

where Equation 2 to 4 represent the color function for each AP's, the Equation 5 is the function to determine L value on each grid (x) position. Figure 2 show the illustration of the process on creating combination color radio map. First, the collected signal from each AP is filtered before converted into its gradation color map. Then create a new color radio map as a function of the sum from 3 different color radio maps. The sum of 3 color based on its RGB value that summary with OR operation.

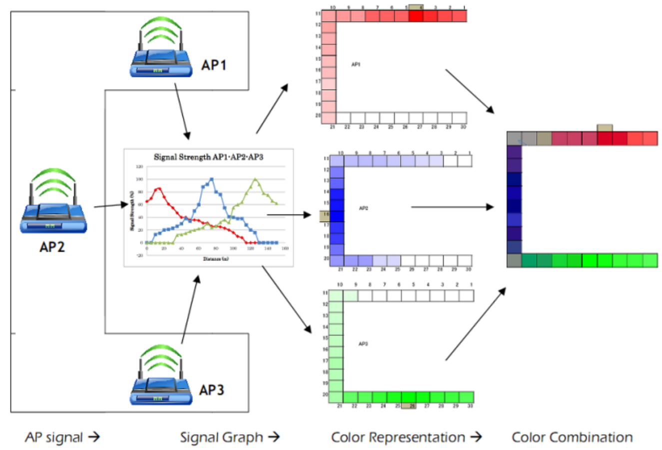


Fig. 2. Flow Diagram on creating Color Radio Map by color combination from 3 different AP signal strength.

D. Interpolation with Color Grid Fusion

Since the initial radio map with the initial grid size is not accurate enough, we improved the radiomap by interpolation. The effectiveness of this method is the interpolation using color information of each grid using grid fusion technique. We start with cell or grid size of 5 meters long with 2.5 widths (the corridor width). This initial grid size is determined into a number that low cost on offline training. The initial color *radiomap* will have the initial error also around 5 meters. Then, to improve the accuracy of the system; the initial map is improved to create a new map with detailed color. Initial grid size is fission into half size and the new value calculating by interpolation between two existing grid. Figure 3 show the illustration of grid fusion technique.

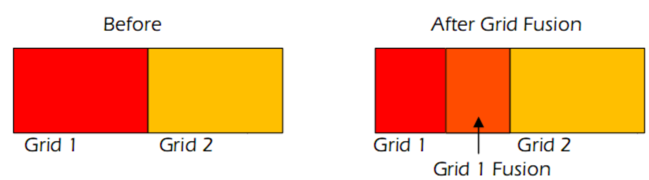


Fig. 3. Illustration of Grid Fusion for color interpolation

The fission of the grid is half size and the color is based on the RGB combination of two adjacent colors using the formula:

$$Grid_1Fusion(r,g,b) = Grid_1(r_1,g_1,b_1) + Grid_2(r_2,g_2,b_2)$$

$$r = (r_1+r_2)/2,\ g = (g_1+g_2)/2 \text{ and } b = (b_1+b_2)/2, \qquad (6)$$

where r is decimal value of *Red*, g for *Green* and b for *Blue* of the grid color. For example, if initial Grid 1 and Grid 2 has the RGB color is $Grid_1$ *(255,0,0)*, and $Grid_2$ *(255, 102, 0)*, then the Grid 1 Fusion become (*255*, *51*, *0*). Interpolation for each adjacent grid generates a new grid with more detail color map as shown in Figure 7. The second stage of grid fusion is aim to create a more detail color radio map grid by using existing signal strength data from initial offline phase. The accuracy of detailed color *radiomap* then measured the investigate the accuracy.

E. User Location Estimation & Visualization

The user location determination process is based on the comparison between real-time online data and predefined offline color *radiomap* to find the minimum error between these two values on its color RGB value. Assume that online signal strength data from 3 AP's is converted into its HSL value then combined into one color using the same process like creating offline map, the RGB representative is (r_s, g_s, b_s). Then the minimum error function is examined to all grid position $Grid_x(r_x, g_s, b_s)$ to find the minimum error using minimum square error (MSE) formula:

$$MSE = [(r_x-r_s)^2+(g_x-g_s)^2+(b_x-b_s)^2]/3 \quad (7)$$

Indoor location estimation system is integrated with online real time monitoring systems. Using color combination technique for position estimation, the monitoring and visualizations of the estimate position becoming easier. Simple color masking technique using input color information as a representation of the combination of 3 signal strength of a user's device measurement at the moment, we can calculate and directly show the user position without using mean square error formula. The method for determine user position in a grid using color layering combination based on this algorithm:

```
// initial variable
input UserSS; // rgb representative of input
user detected signal strength
var NewLayer; // create new layer image
var maxGridNumber; // maximum grid number

for x=1 to maxGridNumber
{
  tempX = (binary(UserSS(x) XOR Grid(x))
  if (decimal(tempX) == 0)
    Newlayer(x) = Grid(x)
  else
    Newlayer(x) = whiteColor + tempX;
}
return NewLayer;
```

Fig. 4. Grid Masking Algorithm for efficient user tracking.

By using this masking algorithm, information about user estimation position automatically show on the new layer image only by masking user input data to color *radiomap* grid. This algorithm work for both online tracking user's position as well as on immediacy user position estimation. This approach is effective since no mathematical calculation for finding the MSE but only graphics processing that directly show the output of user position into the monitoring system.

IV. EXPERIMENTAL EVALUATION

A. System Testbed

We performed the experiment in the third floor of the Engineering faculty Building 1, Saga University. This building has a layout like C alphabet as shown in Figure 2 with the total dimension in a rectangle is 150 × 2.5 meters. The building is equipped with 802.11b wireless LAN environment. To form the radio map, the environment was modeled as a space of 30 cell locations in a grid of 5 x 2.5 meters each. This size is chosen as starting cell grid size, then interpolates it to make more detailed map with color *radiomap* interpolation.

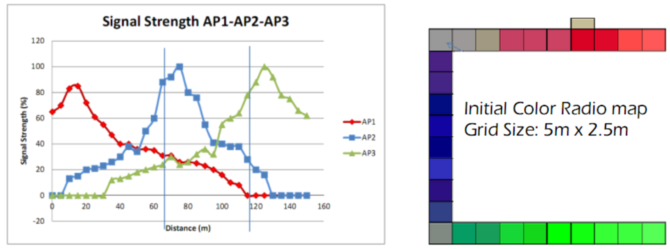
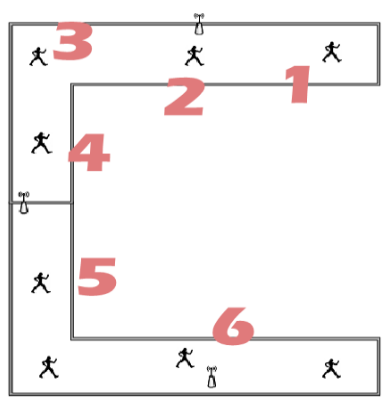


Fig. 5. Graph of Signal Strength Measured from 3 AP (left) and its combination color radiomap (right)

Since we deem that train data on too many locations on offline phase is impractical, we attempt to calibrate in few locations and interpolate all the other data on grid points by our model. In the experiment environment, we collected 1 point on the centre of each grid with sample number is 20 for each grid, and select the median value. The recorded signal strength information of each AP then translated to its color representation using Equation 1 to 4, to get the color *radiomap*. Finally, we combine the 3 color *radiomap* from different AP data into one map. The initial offline measurement results graph of training phase and the combination of color radio map is shown in Figure 5.

For evaluating the accuracy of proposed system, we conduct online tracking experiment and measure the results accuracy and errors. The evaluation phase use data from 25 random positions between 1 to 150 meters. To illustrate the experiment process we choose 6 position of user as initial online tracking position as shown in Figure 6; assume that measurement start from top right through the bottom right. The position of AP's is



Position

1. 3 meters
2. 15 meters
3. 46 meters
4. 72 meters
5. 92 meters
6. 132 meters

Fig. 6. Online tracking random sample position.

B. Experiment Results

The results of the experiments on the 6 random positions show that proposed system succeed to determine the user position by using information from measured signal strength from 3 AP's to the user device. Table 1 shows the results of estimated grid and the errors for the testing positions. Because the results are in the cell grid position which is a rectangle area, not a point position, the distance error is measured by taking the maximum of absolute number of the difference between the real positions to each grid border. Maximum difference between grid border size and real position is called as maximum error and the minimum difference between grid border point and the real position is called as minimum error. For example, first test position is 3 meter and the estimated grid is the grid number 1 which is located at 0 meters to 5 meters, so the maximum error is 3 meters and minimum error is 2 meters. The average error for 6 samples with initial color radio map is 3.5 meters. This error is quite enough for victim location estimator in disaster management system, but still not accurate enough as a precise indoor location estimation system. We can improve the accuracy by creating the new *radiomap* with smaller grid size using color *radiomap* interpolation method.

TABLE I. GRID ESTIMATION RESULTS FOR 6 SAMPLES WITH ERROR

No	*Online Position (meters)*	*Estimated Grid*	*Min Error (meters)*	*Max Error (meters)*
1.	3	Grid 1 [0m-5m]	2	3
2.	15	Grid 2 [15m-20m]	0	5
3.	46	Grid 10 [45m-50m]	1	4
4.	72	Grid 15 [70m-75m]	2	3
5.	92	Grid 19 [90m-95m]	2	3
6	132	Grid 27 [130m-135m]	3	3

C. Efficiency and Accuracy of Grid Fusion

Initial color *radiomap* with 5 meter width of grid size, has minimum error 1.5 meters and maximum error 3.5 meters of the average error for 6 sample point. To improve the accuracy, we create a new map by reduce the grid size and interpolate the value from initial map. Two level grid fusions from 5 meters to 2.5 meters and from 2.5 meters to 1.25 meters size is created as shown in Figure 7 with the illustrate to show the color matching results. Figure 7 (bottom) also show the estimation position results for starting grid size and after interpolate into half size of the starting grid.

To evaluate the effectiveness and accuracy of proposed color grid interpolation method, we create another color radiomap start with grid size 8 x 2.5 meters then fission interpolate into 4 meters grid and 2 meters grid. Figure 8 show the graph of accuracy error from 2 color *radiomap* scheme for 25 samples from random position as online testing data. Radio Map with grid size 2.5 x 2.5 meters has average error 2.39 meters while radio map grid C with grid size 1.25 x 2.5 meters has average error 1.59 meters. Improvement of color radio map with smaller grid size has decrease the accuracy error as shown in Figure 8. The experiments show that grid fission with color interpolation has significantly reduced the accuracy error. From the results, we found also that smaller initial cell grid size perform better than larger initial cell grid size.

The accuracy and effectiveness of our method is also compared with other previous method on indoor location estimation especially fingerprint and deterministic based method. Table 2 shows the comparison on the accuracy and the complexity for creating *radiomap*.

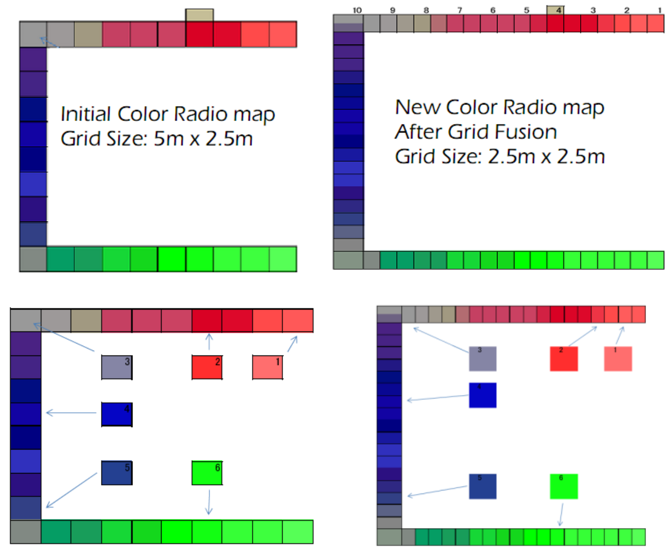


Fig. 7. Online tracking random sample position..

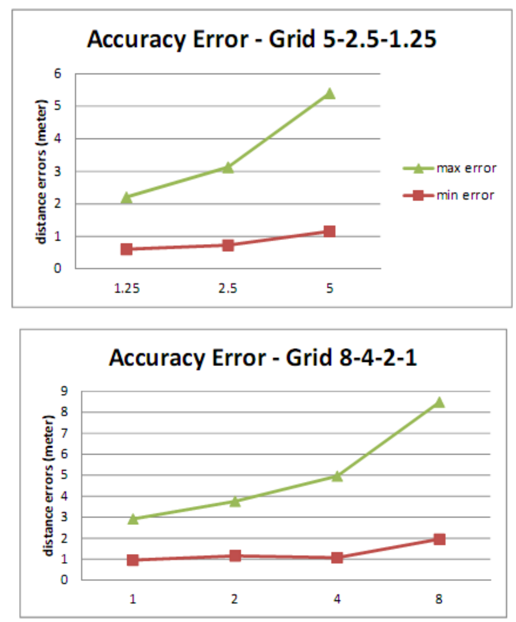


Fig. 8. Accuracy Error Graph of two map gradation. 5 meters scheme (top), and 8 meters scheme (bottom)

The accuracy means the distance error between real locations comparing to estimated results from the system. We use the mean error value (average of max error and min error) to compare the estimation error. Complexity means the effort on calibration process for creating radiomap or fingerprint database. The complexity is determined into 3 levels as follows: relatively high complexity, medium complexity, simple complexity. Comparing with other method, proposed color radiomap interpolation show high accuracy with simple complexity superior to RADAR one of the famed location estimation systems. Tzu Chieh [8] reported that they has 0.9076 meter on accuracy error but still in medium complexity on reducing calibration effort, while our method results can compete but with less complexity. Krumm [8] also show the simple complexity but the accuracy error still high above 3 meters error.

TABLE II. ACCURACY AND EFFICIENCY COMPARISON

No	***Method***	***Estimation Error (meters)***	***Complexity***
1.	RADAR [3]	1.7588	High
2.	Tzu Chieh [8]	0.9076	Medium
3.	J Krumm [5]	3.75	Simple
3.	Proposed Method	1.108	Simple

V. CONCLUSION AND FUTURE WORK

In this paper, we empirically study the effect of reducing the calibration effort on estimate the fingerprint radio map by interpolate new map with smaller grid size using color *radiomap* interpolation method. Both the offline and online phase is based on color combination and gradation interpolation method. Experiments show that creating new accurate map with interpolate unlabeled area using color information has reducing the calibration process while achieve high accuracy. Also, the determination of the user position can be done more effectively through the image processing integrated in monitoring and visualization systems.

We compare our system with some other famed location estimation system and demonstrate that our system perform simple complexity while gain high accuracy compare to others method.

In the future, we plan to improve this method to find the best grid size and implement it on user monitoring system for disaster management system. Moreover, we intend to test the validity of our proposed method in other complex building with many rooms and floor. The effect of using more or less than 3 AP is also considered for future investigation.

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Content Based Image Retrieval by using Multi Layer Centroid Contour Distance

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***Abstract*—In this paper we present a new approach to measuring similarity between two shape of object. In conventional method, centroid contour distance (CCD) is formed by measuring distance between centroid (center) and boundary of object, but this method cannot capture if an object have multiple boundary in the same angle. We develop a novel approach feature shape by measuring distance between centroid (center) and boundary of object that can capture multiple boundaries in the same angle or multi-layer centroid contour distance (MLCCD). The experiment result on simulation dataset and plankton dataset show that the proposed method (MLCCD) better than the conventional method (CCD).**

***Keywords*— Content based Image Retrieval; CCD; MLCCD**

I. INTRODUCTION

Recently every time amount of image in the world is increasing very fast and there is a big concern to recognize an object in large collections of image databases. Image database every time become bigger and it make a problem dealing with database organization so the necessity of efficient algorithm is obvious needed [1].

Content based image retrieval(CBIR) also known as query by image content is technique which uses visual content that well known as features for extracting similar images from an image in database [2][3][4]. On The Content based Image Retrieval (CBIR) local feature of an image is computed at some point of interest location in order to recognizing an object. In order to recognize the object firstly the image has to be represented by a feature vector. This feature vector be converted to different domain to make simple and efficient image characteristic, classification and indexing [5].

Many techniques to extract the image feature is proposed [6][7][8] [9]. Shape is one of important visual feature of an image and used to describe image content [8]. The Centroid contour distance (CCD) is formed by measuring distance between centroid (center) and boundary of object [10].

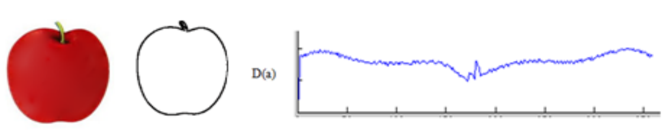

Fig. 1. An object and its centroid distance signature

Figure1 is image apple, boundary of object apple and its centroid distance signature. D(a) is distance between center of object and the boundary of object with angle a (from 0 to 360). Suppose center object is (Xc,Yc) and b is point in the boundary of object with coordinate (X_b, Y_b). The distance (Dn) between center and the point in the boundary:

$$D_n = \sqrt{(X_b - X_c)^2 + (Y_b - Y_c)^2} \quad (1)$$

And the CCD feature is :

CCD = [D1, D2, D3, …,Dn]

Where:

Dn = Distance between center and point number n in the Boundary of object.

n = Total point in the boundary of object.

The remainder of this paper will be organized into the following sections: in the section Two, Proposed method, The third section will describe Similarity and performance, The experiment results will be discussed in the fourth section and finally, the fifth section will provide conclusions.

II. PROPOSED METHOD

Figure 2 is Diagram block of the proposed CBIR.

Firstly images in the database image one by one are extracted. The local feature of an image at some point at interest location is computed. Interest location of the local feature can be obtained by converting RGB image to gray image and implement the canny filter to detect edge position then use morphology filter to ensure the shape of object clear. Feature vector is computed by measuring distance between center of object and point in the boundary object then the result is placed to the feature vector layer 1 if the object has multiple points in the same angle (see fig.3) the result is placed into next layer. All images in the database image is processed by using same method and the output is placed into database of feature vector retrieval.

Secondly, when a query image is provided then applied same method to obtain feature vector. These feature vector is compared with other feature vector that exist in the database of feature vector retrieval by using the Euclidean distance.

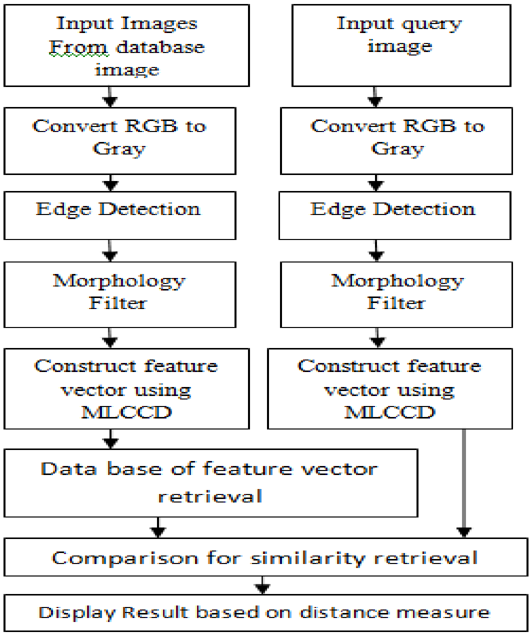

Fig. 2. Diagram block of Proposed Cbir

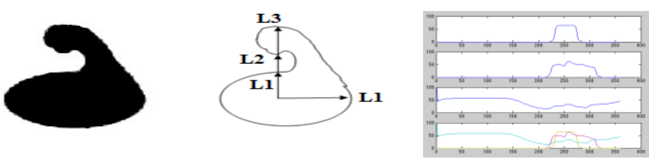

Fig. 3. An object and its multi layer centroid contour distance (MLCCD) signature

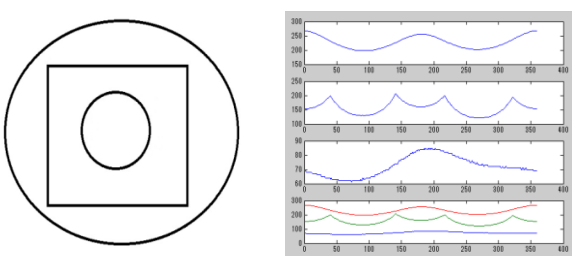

Fig. 4. An object and its multi layer centroid contour distance (MLCCD) signature

In figure 3 when the angle 0 there is one point have to be captured. However, when the angle is 270 degree there are three point have to be captured by using MLCCD in these case other method just capture one point. In figure 4, the object has three point that have to be captured for all different angle and the result is placed into three layer.

In order to obtain the MLCCD firstly position of the centroid have to be computed(see equation 2) then calculate the distance between centroid and the boundary of object repeat this method for other boundary in same angle and different angle.

Position of the centroid is:

$$X_c = \frac{X_1+X_2+X_3+....+X_n}{n} \quad , \quad Y_c = \frac{Y_1+Y_2+Y_3+....+Y_n}{n} \qquad (2)$$

The computed distances are saved in a vector. In order to achieve rotation invariance, scale invariance and translation invariance implementation shifting and normalization to these vector is needed.

III. Similarity And Performance

A. Similarity Measurements

Similarity metric is very important on the retrieval result. The similarity measure is computed by using Euclidean distance (See Eq.0) between feature representation of image in database image and feature representation of image query. These feature representation is image feature that refer to the characteristics which describe the contents of an image. The retrieval result is a list of image ranked by their similarity.

Suppose S_1 and S_2 are shape of object represented multi layer of feature vectors each (db_1, db_2,…,db_k) and qr_1, qr_2,.....,qr_k) then the Distance between S_1 and S_2 is:

$$dis(F_{db}, F_{qr}) = \sqrt{\sum_{j=1}^{k} (db_j - qr_j)^2} \qquad (3)$$

Where:

Fdb = Feature vector of image in database image

Fqr = Feature vector of query image.

k = Number element of feature vector

in these case if the distance between feature representation of image in database image and feature representation of image query small enough then it to be considered as similar.

B. Performance Measurements

In order to measure the performance of the CBIR system we used precision and recall. Precision measures the retrieval accuracy; it is ratio between the number of relevant images retrieved and the total number of images retrieved (see equation 4). Recall measures the ability of retrieving all relevant images in collection. It is ratio between the number of relevant images retrieved and the total number of relevant images in the collection(see equation 5).

$$\textbf{Precision} = \frac{\text{Number of relevant images retrieved}}{\text{Total number of images retrieved}} \qquad (4)$$

$$\textbf{Recall} = \frac{\text{Number of relevant images retrieved}}{\text{Total number of relevant images in the collection}} \qquad (5)$$

IV. Experiment V

A. Experiment by using Simulation data

A. Simulation

We use simulation dataset and real dataset for comparison the new approach and the conventional approach.

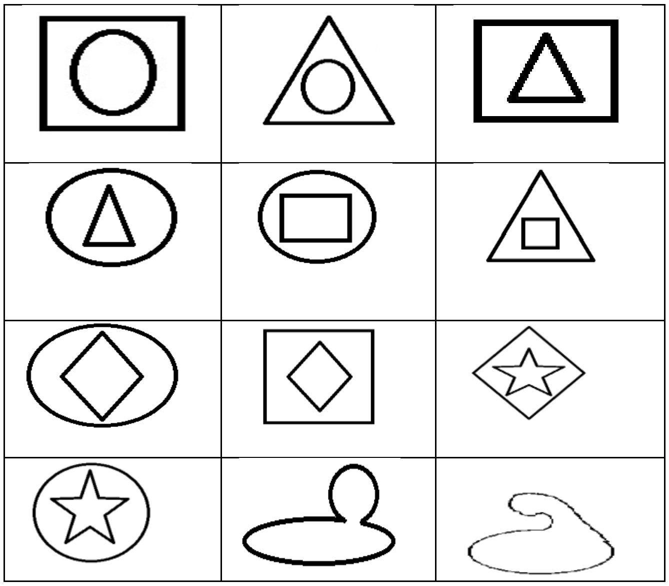

Fig. 5. Example of simulation dataset

The simulation dataset consist combination of curve shape, oval shape, rectangle shape, Triangle shape, Diamond shape, star shape as shown in Figure 5. Also we make these shapes with different scaling, translation and rotation as shown in Table 1. Graphic average precision results on simulation dataset are then shown in Figure 6.

TABLE I. AVERAGE PRECISION ON SIMULATION DATASET

Number Group	Shape	CCD	MLCCD
1	oval rectangle	86	93
2	oval triangle	80	85
3	Triangle rectangle	81	86
4	Rectangle oval	80	85
5	Triangle oval	70	75
6	rectangle triangle	88	96
7	Diamond oval	85	89
8	Diamond rectangle	68	92
9	Star diamond	74	85
10	Star oval	67	81
11	shape with concave 1	85	91
12	shape with concave 2	83	93
Average		78.91	87.58

The experiment on the simulation dataset in the table 1 and graphic in figure 6 are obtained base on equation 4 shows average precision result is superior to the conventional method for all cases by approximately 8.67 %.

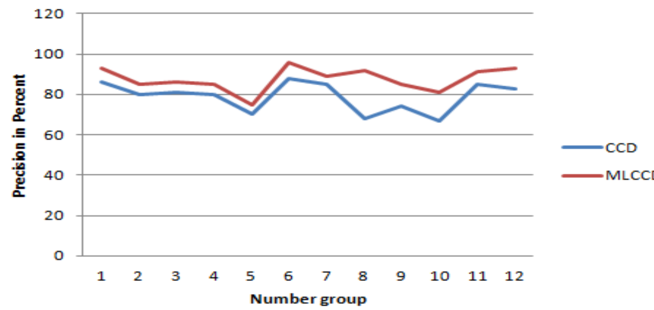

Fig. 6. Graphic Average precision on simulation dataset

B. Experiment with real image

In order to show the feasibility of the shape recognition scheme, we used Image database of phytoplankton [11] for experiment to real data. On the phytoplankton, Algal blooms (red tides) are a phenomenon of clear ecological importance in many regions of the world. Caused by a nutrient influx (e.g. agricultural pollution) into the ocean, by either natural or anthropogenic causes, they can be toxic to marine life [12] and humans under certain conditions.

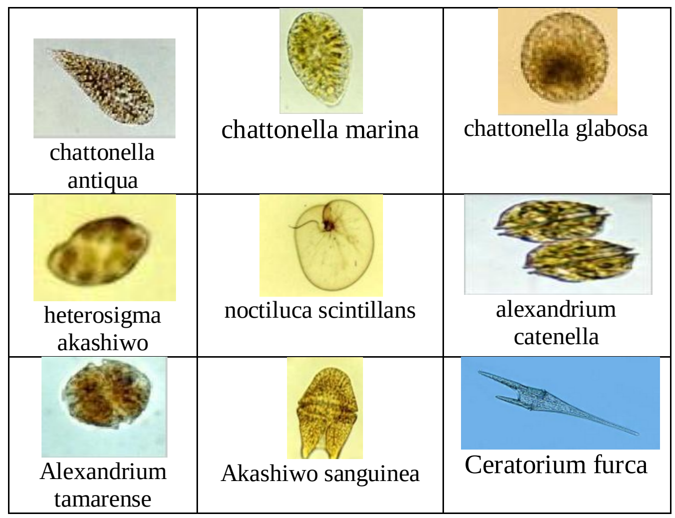

Fig. 7. A small portion of phytoplankton image database

Red tide is a significant problem not only for fisherman but also ocean biologist. Red tide is one of measure for representation of ocean healthy [13]. Red tide occur in a nutrition rich ocean. Nutrition rich water makes chlorophyll-a then phytoplankton is increase thus red tide occurs. Figure 7 shows a portion of phytoplankton image database.

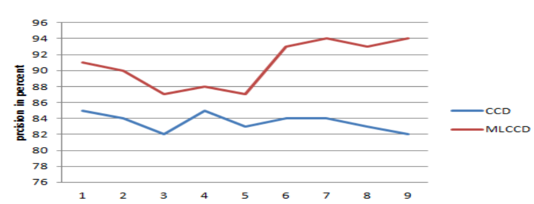

Fig. 8. Graphic Average precision and recall on real dataset

TABLE II. AVERAGE PRECISION ON REAL DATASET

Number Group	Total Image	Phytoplankton name	precision		Recall	
			CCD	ML CCD	CCD	ML CCD
1	18	chattonella antiqua	85	91	47	50
2	17	chattonella marina	84	90	49	52
3	17	chattonella glabosa	82	87	48	51
4	17	heterosigma akashiwo	85	88	50	51
5	17	noctiluca scintillans	83	87	48	51
6	20	alexandrium catenella	84	93	42	46
7	22	Alexandrium tamarense	84	94	38	42
8	23	Akashiwo sanguinea	83	93	36	40
9	24	Ceratorium furca	82	94	34	39
		Average	83.5	90.7	43.5	46.8

In order to detect red tide, many researcher check phytoplankton in water sampled from the ocean with microscope. Immediately after they check phytoplankton, they have to identify the species of phytoplankton. Image retrieval is needed for identification. The proposed method is to be used for image retrieval and identification.

The experiment on the real dataset in the table 2 is precision measure base on equation 4 and recall measure base on equation 5. Average precision result by using new approach is higher 3 percent (see in group 4 heterosigma akashiwo) up to 12 percent (see in group 9 Ceratorium furca) rather than the coventional method also for average recall result by using new approach is higher 1 percent up to 5 percent rather than conventional method. From the experiment show if the image have more concave then differences of result between new approach and the conventional method will increase see graphic in figure 8 and figure 9. From these table and figure, it may said that the proposed method is superior to the conventional method for all cases by approximately 7.22 %.

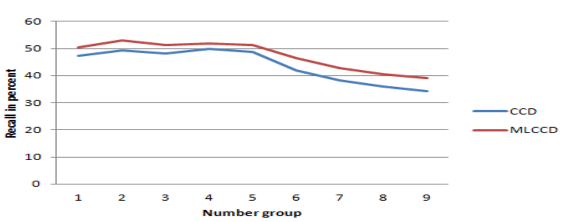

Fig. 9. Graphic Average recall on real dataset

V. CONCLUSION

In this research, we propose a new approach to extract features of an object shape that has some points with the same angle. In the conventional method if there is multiple points in same angle just capture one point that nearest to the centroid and placed to one layer. While using the proposed method if there is multiple points in the same angle all point will be captured and the result be placed into multiple vector layers.

The experiment results on simulated data demonstrate a new approach has the advantage of 8.67 percent higher than using conventional method. Precision results on real data (real data on phytoplankton dataset) with a new approach has also the advantage of 7.22 percent higher than using conventional method.

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Predicting Quality of Answer in Collaborative Q/A Community

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***Abstract*— Community Question Answering (CQA) services have emerged allowing information seekers pose their information need which is questions and receive answers from their fellow users, also participate in evaluating the questions or answers in a variety of topics. Within this community information seekers could interact and get information from a wide range of users, forming a heterogeneous social networks and interaction between users. A question may receive multiple answers from multiple users and the asker or the fellow users could choose the best answer. Freedom and convenience in participation, led to the diversity of the information. In this paper we present a general model to predict quality of information in a CQA by using non textual features. We showing and testing our quality measurement to a collection of question and answer pairs. In the future our models and predictions could be useful for predictor quality information as a recommender system to complete a collaborative learning.**

Keywords—component; Collaborative; diversity of information; questions; answers; predict; non-textual feature

I. INTRODUCTION

Community Question Answering (CQA) has recently become available for information seekers. Beside web search engines, information seekers today have an option to inform their questions on CQA sites and answered by other users. Comparing with information through search engines such as Google [1] [6], which the results are not always correspond to user requirements, in Community Question Answering (CQA) information seekers provides the information needed by other users such as Yahoo! Answer, Naver or Answer Bag.

These communities have become quite popular in the last several years for a number of reasons. First, because of the targeted response from users with knowledge or experience, it is making users more useful and easy to understand the information. Second, the information also provides consolidated communication environment in which the information related to the questions could be seen. This environment facilitates multiple answers (likely from a different perspective) and discussion (in the form of comments) which could benefit the questioner (and others as well).

By clarification and suggestion (using email or other means), it is possible for the questioner to interact with the answerer. This paradigm is, although, quite different from the instantaneous search for stored information, this is likely to provide the questioner with useful answer. Finally, the forum provides an incentive for the users to show their skills and in the process get acknowledged by the community. Such as collaborative learning, users could exploit and share their resources and skills by asking information, evaluating, monitoring one another's information and idea.

Many CQA service providing non-textual information related to their document collections. Usually textual features are used to measure relevance of the document to the query and non textual features can be utilized to estimate the quality of the document. The information from non-textual feature has potential for improving search quality [2] such as points, best answers, contributor etc. In the other hand, the quality of information given by traditional content could be favorable and trusted. For the social media of CQA, the quality of information is diverse, from the high-quality, low-quality or spam. The quality of an answer or of any information in document content for that matter could be subjective.

Jeon et al [2] [3] using non-textual features to predict quality of answers. They collected Q&A pair of data and 13 features from the Naver Q&A service which is written in Korean.

To handle various types of non-textual features and build a stochastic process that could predict the quality of documents, they use kernel density estimation [12] and maximum entropy approach. [13] Introduce the problem of predicting information seekers satisfaction in collaborative question answering communities. [16] also trying to predict selected information by using 13 quality criteria to evaluated the answers (5-point Likert scale) and 9 feature. Occasionally, answerer's temporal characteristic could significantly contribute to the quality of an answer beside activity feature [17]. This paper presents a method for systematically processing non-textual feature to predict the quality of information collected from specific Indonesian web service (id. Y!A) using classifier.

II. PROPOSED METHOD AND SYSTEM

A. System Architecture

The proposed method in this paper consists of four parts. There are data collection, feature extraction, coefficient correlation with an answers, and classification. Figure 1 showing the architecture of the proposed system.

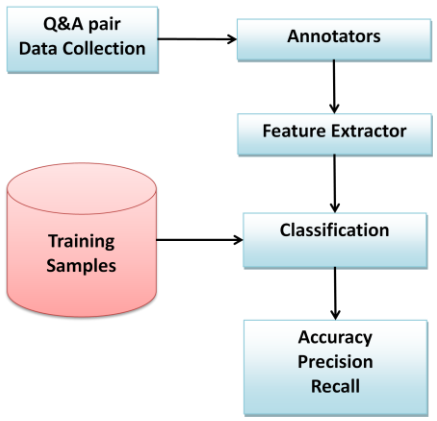

Fig. 1. Architecture of The Proposed System

B. *Data Collection*

Our data is based on a snapshot of Yahoo! Answer for Indonesian people (http://id.answers.yahoo.com/), a popular CQA site. Our first step is collecting categories that have the highest activity (question resolved) from the 26 category. From table 1, we could see a category that has high activity. There are music and entertainment category, society and culture category, computers and internet category, family and relationship category, and the last consumer and electronic category.

TABLE I. ACTIVITY FOR 5 HIGHSET CATEGORY RESOLVED

Category	Resolved	Resolved question for each category ratio
Music and entertainment	436224	39656
Society and culture	377993	37799
Internet and computer	258870	36981
Family and relationship	123846	20641
Consumer and electronic	102513	9319

(Taken in July - August, 2012)

In order to focus on a realistic question and answer, we choose internet and computer category. The selection is based on the idea that several sub category on music entertainment and society culture providing highly subjective answer such as religion and spirituality.

We collected 258870 Q&A pairs from id.Y!A service (internet and computer), all question and answer are written in Indonesian. We randomly selected resolved question from 7 sub category and all we found 1500 Q&A pairs. The quality of a Q&A depends on the question part and answer part. For the question part we use most popular resolved question. Users could not get any useful information from bad questions. The reality bad questions always lead to bad quality answers. Therefore we decide to estimate only the quality of answers and consider it as the quality of the Q&A. In the Y!A CQA, multiple answers are possible for a single question and the questioners selects the best answer. We extract features only from the best answer. We use statement for evaluating answers [13]. The asker personally has closed the question and selected the best answer; also provide a rating of at least 3 stars for the best answer quality.

The information of CQA is typically complex and subjective. We use annotators for manual judgment of answer quality and relevance. General, good answers tend to be relevant, information, objective, sincere and readable. We may separately measure these individual factors and combine scores to calculate overall the quality of the answer. Therefore, we propose to use a holistic view to decide the quality of an answer. Our annotators read answers, consider all of the above factors and specify the quality of answers in three levels: Bad, Medium and Good (in the future classified as good, medium and bad).

C. *Feature Extraction*

First we will extract feature vectors from a Q&A pair (answer yahoo). We extract 18 non-textual features, divide as answer feature/AF (feature 1 to 8) and answerer user history/AUH (feature 9 to16). Because in community question answer, multiple answers for single answer are possible. We extract features only form the questioner selects (best answer). The features are;

(1) Star: Number of stars that given by questioners from one to five stars to the answer.

(2) Reference: When answer the question; sometime answerer's give the reference for the answer.

(3) Vote-up: Number of positive votes.

(4) Vote down: Number of negative votes.

(5) Contributor: Answerer's, who are specifically in several categories.

(6) Character length: Number of characters for the answer.

(7) World length: Number of words for the answer.

(8) Sentences length: Number of sentences for the answer.

(9) Member since: How long since last registration from the all activity.

(10) Answerer's activity level: Answerer's activity level.

(11) Answerer's total point: Total point from all the answer.

(12) Total number of answer: Total number of all answerer's that answers answered previously.

(13) Number of best answer: Total number of best answer.

(14) Best answerers acceptance ratio: The ratio between best answers to all the answers that the answers answered previously.

(15) Number of other answer: Total number of other answer (not best answer) that answerer's answered previously.

(16) Answerers other acceptance ratio: Ratio of other answers (not best answer) to all the answerer's answered previously.

(17) Best and other answer ratio: Ratio of best answers to the other answers previously.

(18) Answer question ratio: Ratio of all answer to the entire question previously.

D. Correlation Coefficient

The function of the correlation coefficient is to know how closely one variable is related to another variable [4], in this case the correlation between individual features and the annotators scores (good answers have higher scores: Bad = 0, Medium = 1, Good = 2). Table 2 showing 13 features' that have strongest correlation with the quality of answer. Surprisingly, number of char and number of word have the strongest correlation with the quality of the answer. On the other side, number of star is not the feature that has strongest correlation with the quality of the answer. This means the number of stars that given by questioners evaluation is subjectively, some of users opinion does not agree with the answer. Almost users appreciate getting answers regardless of the quality of the answers. This user behavior may be related to the culture of Indonesian users, same as Korean users [2].

The formula for Pearson's Correlation Coefficient:

$$r_{xy} = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{n}}{\sqrt{\left[\sum X^2 - \frac{(\sum X)^2}{n_x}\right]\left[\sum Y^2 - \frac{(\sum Y)^2}{n_y}\right]}} \quad (1)$$

TABLE II. COEFFICIENT CORRELATION

Features	Correlation
Star	0.3391
Contributor	0.3323
Member since	0.2147
Activity level	0.4705
Total point	0.4285
Total answer	0.4464
Best answer	0.4435
Ratio best answer	0.3323
Other answer	0.3846
Number of char	0.6391
Number of word	0.6607
Number of sentence	0.5740
Answer question ratio	0.2303

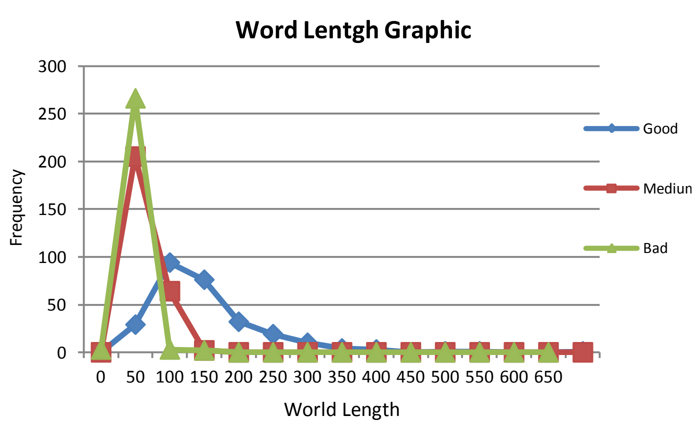

Fig. 2. Distributions of Word Length

Figure 2 show the distributions of good, medium and bad quality answer for word length. Good answers are usually longer than bad and medium answer.

E. Classification Algorithms

We explored Decision Tress, Boosting and Naïve Bayes, using Weka framework [15]. Using a decision tree classifier, we expect o get high precision on the target class. Support vector machines are considered the classifier of choice for many tasks, and to handle the noisy features use AdaBoost. Using Naïve Bayes cause has performed very simple and fast, effective method to investigate the success of our experiment.

III. Implementation and Results

We l implement the proposed methods to the Q&A pair of data. There are four kind data for the classification, data from the entire feature, data with high correlation (> 0.1 and > -0.1), data from answer feature, and data from answer user history. We build the predictor using 815 training data and 302 testing data (from the annotators we get 1117 related Q&A pair data). Table 3 reports prediction accuracy for different implementations, comparing the choice in classifier algorithm and features for training set, testing set also in 5 cross validation

TABLE III. ACCURACY OF TRAINING FOR EACH FEATURE

Classifier	All	Corr	AF	AUH
Naïve Bayes	73.13	69.73	79.14	50.80
Adaboost	81.10	80.27	81.10	53
C4.5	91.90	91.42	88.83	66.50

Table 3 reports prediction accuracy for the different implementation of answer quality, in particular comparing the choice in classifier algorithm, feature sets (using all feature, Correlation feature, answer feature, answerer history feature) and test option. Surprisingly C4.5 results in the best performance of all the classification variants, with accuracy on the satisfied class of 91.9 for all features. From the same table we could see that by using answer feature (AF) and answerer user history (AUH) the accuracy it is not so good, especially for answerer user history. For the answer feature is closed to within 3.07 with all feature and 2.59 with Correlation feature.

The geometric mean of precision and recall measures (F1) reported in Table 4. We could see from all feature set and Correlation feature set by using test option, C4.5 have higher F1 for 91.9, training set, 89.1 testing set and 81 using 5 cross validation. Another interesting result from Table 4 and 5 we could see that the differences between all features and Correlation feature, is not too significant for accuracy it is about 0,52. This indicates that feature which does not have high correlation is not too pretty significant impact for classification results.

TABLE IV. PRECISSION AND RECALL OF ALL FEATURE, CORR FEATURE

Classifier		all			Correlation		
		cv = 5	**Train**	**Test**	**cv = 5**	**Train**	**Test**
Naïve Bayes	F1	72.3	72.7	65.8	68.9	62.6	68.6
	Accuracy	72.26	73.13	65.56	69.98	69.73	62.91
Ada boost	F1	80	80.6	79.7	79.2	79.8	76.6
	Accuracy	80.12	81.10	79.80	79.66	80.27	76.82
C4.5	F1	**81**	**91.9**	**89.1**	79.9	91.4	89.1
	Accuracy	**80.98**	**91.90**	**89.07**	79.90	91.42	87.09

TABLE V. ACCURACY OF ALL FEATURE AND CORR FEATURE

Classifier		all			Correlation		
		cv = 5	**Train**	**Test**	**cv = 5**	**Train**	**Test**
Naïve Bayes	Precission	72.4	72.8	66.7	69.8	63.9	69.7
	Recall	72.8	73.1	65.6	70	62.9	69.7
Ada boost	Precission	80.2	81	80	79.9	80.7	78
	Recall	80.1	81.1	79.8	79.7	80.3	76.8
C4.5	Precission	**81.1**	**91.9**	**89.2**	80	91.4	89.3
	Recall	**81**	**91.9**	**89.1**	79.9	91.4	89.1

```
=== Evaluation on training set ===
=== Summary ===

Correctly Classified Instances         749               91.9018 %
Incorrectly Classified Instances        66                8.0982 %
Kappa statistic                          0.8785
Mean absolute error                      0.092
Root mean squared error                  0.2145
Relative absolute error                 20.7059 %
Root relative squared error             45.5037 %
Total Number of Instances              815
```

Fig. 3. Result of Classification on Training Data

```
=== Evaluation on test set ===
=== Summary ===

Correctly Classified Instances         269               89.0728 %
Incorrectly Classified Instances        33               10.9272 %
Kappa statistic                          0.8361
Mean absolute error                      0.111
Root mean squared error                  0.2515
Relative absolute error                 24.9781 %
Root relative squared error             53.3488 %
Total Number of Instances              302
```

Fig. 4. Result of Classification on Testing Data

IV. IMPLEMENTATION AND RESULTS

In this paper we presented our knowledge to quantify and predict quality of answer in question answering communities, especially for Indonesian CQA. Beyond developing models to select best answer and evaluate the quality of answers, there are several important lessons to learn here for measuring content quality in CQA. We find huge variety of question and answer on CQA services, and by given question may several answers are providing from the community.

With appropriate features, we could build models that could have significantly higher probability of identifying the best answer class than classifying a non-best answer.

From the entire system by using Q&A pairs from id.answer yahoo, 18 feature and 3 type classification. We conclude as following:

(19) From the four existing feature, the highest accuracy exist on all feature set (comparing with correlation coefficient set, AF set and AUH set)

(20) The best performance of all classification variants by using C4.5, with average accuracy 91.90 , precision 91.9 and recall 91.9

In the future our models and predictions could be useful for predictor quality information as a recommender system to complete a collaborative learning.

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Rice Crop Field Monitoring System with Radio Controlled Helicopter Based Near Infrared Cameras Through Nitrogen Content Estimation and Its Distribution Monitoring

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***Abstract*—Rice crop field monitoring system with radio controlled helicopter based near infrared cameras is proposed together with nitrogen content estimation method for monitoring its distribution in the field in concern. Through experiments at the Saga Prefectural Agricultural Research Institute: SPARI, it is found that the proposed system works well for monitoring nitrogen content in the rice crop which indicates quality of the rice crop and its distribution in the field in concern. Therefore, it becomes available to maintain the rice crop fields in terms of quality control.**

Keywords-radio controlled helicopter; near infrared camera; nitrogen content in the rice crop leaves; remote sensing;

I. INTRODUCTION

There are strong demands for saving human resources which are required for produce agricultural plants. In particular in Japan, now a day, the number of working peoples for agricultural fields is decreasing quite recently. Furthermore, the ages of the working peoples are getting old. Moreover, the agricultural fields are also getting wide through merging a plenty of relatively small scale of agricultural fields in order for maintain the fields in an efficient manner. Therefore, the working peoples have to maintain their fields in an efficient manner keeping the quality in mind.

Vitality monitoring of vegetation is attempted with photographic cameras [1]. Grow rate monitoring is also attempted with spectral reflectance measurements [2]. One of the methods for monitoring the fields is to use remote sensing technology utilizing aircrafts, helicopters, hot air balloons, etc. with a wide field of view for monitoring relatively large scaled agricultural fields. In particular, there are remote sensing sensors which onboard radio controlled helicopters. Attitude stability of the radio controlled helicopters is getting well now a day. Field of view of the remote sensing sensors is good enough for relatively wide scale of agricultural fields.

One of the indexes which allows indicate quality of agricultural crops is nitrogen content in the agricultural crop leaves. The nitrogen content is proportional to the reflectance at Near Infrared: NIR wavelength regions. Therefore, it is possible to estimate quality of agricultural crops with radio controlled helicopter based near infrared camera data.

Through experiments at the Saga Prefectural Agricultural Research Institute: SPARI for the period of rice crop growing, it is found that the proposed system works well for monitoring quality of the rice crops. Also it is found that the proposed method for nitrogen content estimation with near infrared camera data. Furthermore, it is capable to check rice crop quality distribution in the rice crop fields in concern. Then quality control which depends on location by location of the rice crop fields can be made with the quality monitoring results.

The following section describes the proposed monitoring system and nitrogen content estimation method based on the relation between nitrogen content in the rice crops and near infrared camera data followed by some experiments. Then conclusion is described together with some discussions.

II. PROPOSED SYSTEM

A. *Radio Controlled Helicopter Based Near Infrared Cameras Utilizing Agricultural Field Monitoring System*

The helicopter used for the proposed system is "GrassHOPPER" [1] manufactured by Information & Science Techno-Systems Co. Ltd. The major specification of the radio controlled helicopter used is shown in Table 1. Also, outlook of the helicopter is shown in Figure 1. Canon Powershot S100 [2]

[1] http://www.ists.co.jp/?page_id=892

[2] http://cweb.canon.jp/camera/dcam/lineup/powershot/s110/index.html

(focal length=24mm) is mounted on the GrassHOPPER. It allows acquire images with the following Instantaneous Field of View: IFOV at the certain altitudes, 1.1cm (Altitude=30m) 3.3cm (Altitude=100m) and 5.5cm (Altitude=150m).

Fig. 1. Outlook of the Grasshopper

TABLE I. MAJOR SPECIFICATION OF GRASSHOPPER

Weight	2kg (Helicopter only)
Size	80cm × 80cm × 30m
Payload	600g

In order to measure NIR reflectance, standard plaque whose reflectance is known is required. Spectralon[3] provided by Labsphere Co. Ltd. is well known as well qualified standard plaque. It is not so cheap that photo print papers are used for the proposed system. Therefore, comparative study is needed between Spectralon and the photo print papers.

The proposed system consist Helicopter, NIR camera, photo print paper. Namely, photo print paper is put on the agricultural plantations, tea trees in this case. Then farm areas are observed with helicopter mounted NIR camera. Nitrogen content in agricultural plants, rice crops in this case, is estimated with NIR reflectance.

B. Regressive Analysis for Estimation of Nitrogen Content with NIR Reflectance

Linear regressive equation is expressed in equation (1).

$$N = a R + b \quad (1)$$

where N, R denotes measured Nitrogen content in leaves, and measured Near Infrared: NIR reflectance, respectively while a and b denotes regressive coefficients. There is well known relation between nitrogen content and NIR reflectance. Therefore, regressive analysis based on equation (1) is appropriate.

C. Proposed Method for Rice Crop Quality Evaluation

Rice crop quality can be represented nitrogen content which is closely related to nitrogen content. Furthermore, it is well known that nitrogen content can be represented with NIR reflectance. Therefore, rice crops quality can be evaluated with measured NIR reflectance based on the equation (1).

The proposed method and tea farm area monitoring system with helicopter mounted NIR camera is based on the aforementioned scientific background.

D. Rice Crop Field at Saga Prefectura; Agricultural Research Institute: SPARI

Figure 2 shows outlook of the test site of rice crop field at SPARI [4] which is situated at 33°13'11.5" North, 130°18'39.6"East, and the elevation of 52feet.

III. EXPERIMENTS

A. Experiment Procedure

In accordance with growing of rice crops, spectral reflectance of rice leaves and Green Meter: GM values (reflectance at green wavelength) as well as meteorological data (air temperature, relative humidity, wind direction and wind speed) are collected. MS-720[5] of spectral radiometer which is manufactured by Eiko Co. Ltd. is used for spectral reflectance measurements. Meteorological data collection instrument manufactured by Mistral Co. Ltd. is also used together with GM meter of SPAD 502 Plus[6] manufactured by Konica Minolta Co. Ltd. Figure 2 shows outlook of the Spectralon (right) and the MS-720 (left).

Fig. 2. Outlooks of MS-720 and Spectralon

[3] https://www.google.co.jp/search?q=spectral+labsphere&hl=ja

[4] http://www.pref.saga.lg.jp/web/shigoto/_1075/_32933/ns-nousisetu/nouse/n_seika_h23.html

[5] http://www.yamato-net.co.jp/product/advanced/analysis/radiometer/ms720.htm

[6] http://www.konicaminolta.jp/instruments/products/color/chlorophyll/index.html

Specie of the rice crop is Hiyokumochi[7] which is one of the late growing types of rice species. Hiyokumochi is one of low amylase (and amylopectin rich) of rice species (Rice No.216). Hiyokumochi rice leaves are planted 15 to 20 fluxes per m^2 on June 22 2012. Rice crop fields are divided into 10 different small fields depending on the amount of nutrition including nitrogen ranges from zero to 19 kg/10 a/nitrogen.

Nitrogen of chemical fertilizer is used to put into paddy fields for five times during from June to August. Although rice crops in the 10 different small fields are same species, the way for giving chemical fertilizer are different. Namely, the small field No.1 is defined as there is no chemical fertilizer at all for the field while 9, 11, and 13 kg/ 10 a/ nitrogen of after chemical fertilizer are given for No.2 to 4, respectively, no initial chemical fertilizer though. Meanwhile, 9, 11, 13 kg/10 a/nitrogen are given as after chemical fertilizer for the small field No.5, 6, and 7, respectively in addition to the 3 kg/10 a/nitrogen of initial chemical fertilizer. On the other hand, 12, 14, and 16 kg/10 a /nitrogen are given for the small fields No.5, 6, 7, respectively as after chemical fertilizer in addition to the initial chemical fertilizer of 3 kg/ 10 a/ nitrogen for the small field No. 15, 17, 19, respectively. Therefore, rice crop grow rate differs each other paddy fields depending on the amount of nitrogen of chemical fertilizer.

B. Experimental Results

1) Outlook of the fields: Figure 3 shows how a portion of the small fields in the early stage in June look like. These photos are portions of small field of C4-3 of top view and slant view respectively. Paddy fields are covered with water before rice leave plantation. Therefore, water surface is seen in these photos. These are growing up after that and do look like in July time frame as shown in Figure 4. There is no water surface can be seen any more from this period. After all, rice crops are grown up, and then these are harvested in September. Figure 5 shows how these rice crops look like just before the harvesting.

[7] http://ja.wikipedia.org/wiki/%E3%82%82%E3%81%A1%E7%B1%B3

(a)Slant view of the early stage of rice leaves

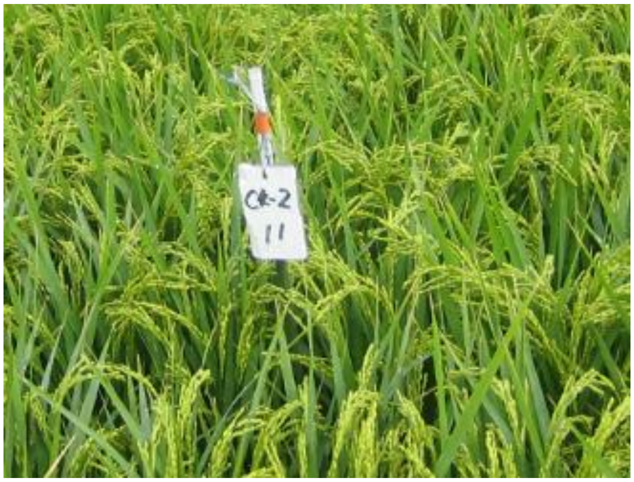
(b)Top view of the early stage of rice leaves

Fig. 3. Outlooks of the early stage of rice leaves in the early stage of rice leaves grow in June 2012.

(a)Top view of the middle stage of rice leaves of C4-2

(b)Top view of the middle stage of rice leaves of C4-3

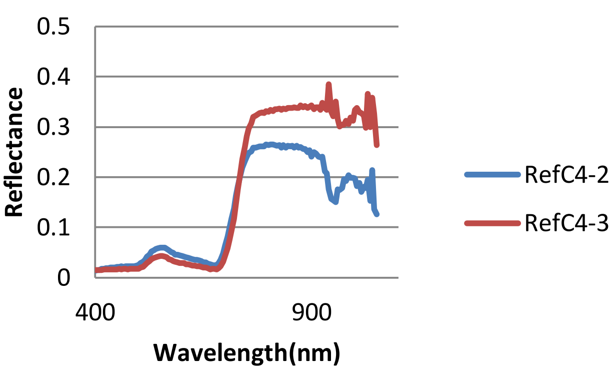
Fig. 4. Outlooks of the early stage of rice leaves in the middle stage of rice leaves grow in July 2012.



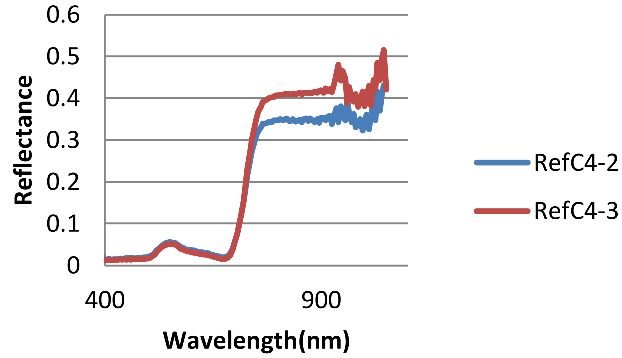
(a)Top view of just before the harvesting stage of rice leaves of C4-2

(b)Top view of just before the harvesting stage of rice leaves of C4-3

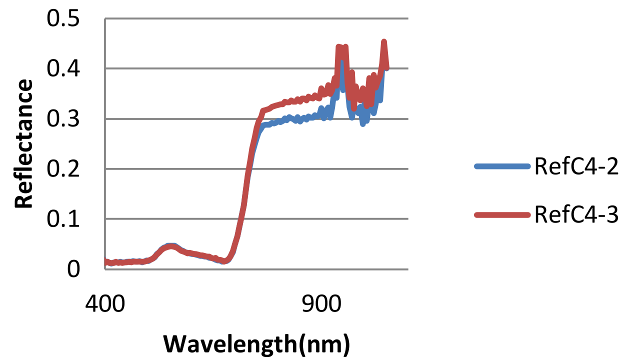
Fig. 5. Outlooks of the early stage of rice leaves in just before the harvesting stage of rice leaves grow in September 2012.



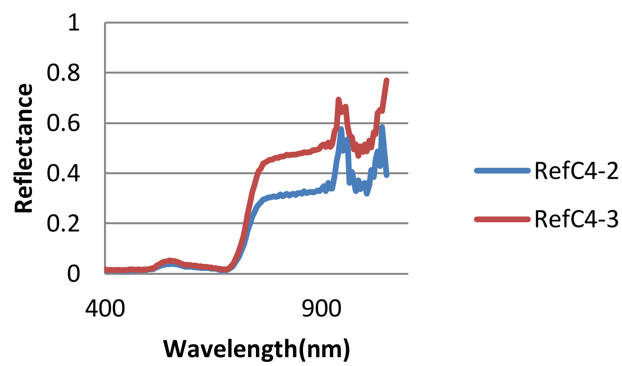
(a)August 15 2012, 13:15：35.6℃,61.0%,3m/s
GM=35.3 (C4-3), 31.0 (C4-2)



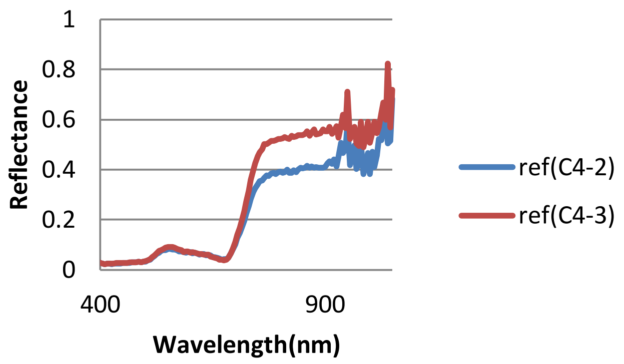
(b)August 17 2012, 9:30：32.2℃, 69.9%
GM=33.5 (C4-3), 32.4 (C4-2)



(c)August 20 2012, 8:45：1.76m/s, 28.9℃, 70%



(d)September 7 2012, 9:00：30.3℃, 72.3%
GM=44.1 (C4-3), 42.4 (C4-2)



(e)September 24 2012, 8:45: 21.2℃, 74.1%
GM=38.8 (C4-2), 45.7 (C4-3)

Fig. 6. Spectral reflectance of NIR reflectance at C4-2 and C4-3 as well as air temperature, relative humidity, and GM values measured at SPARI

2) Surface Reflectance: During the period from August 15 to September 24 2012, spectral reflectance is measured from the top of the rice leaves. Figure 6 shows trend of rice leaf reflectance for C4-2 and C4-3 of the small fields at 700nm measure with MS-720 together with GM values as well as meteorological data.

The reflectance of C4-2 and C4-3 measured at 870nm (NIR reflectance) as well as GM values for these small fields are summarized in Table 2. Also these values are shown in Figure 7. NIR reflectance is increased with time during rice leaves are growing together with GM value. The rice crops are harvested in the begging of October. It is also confirmed that GM value and NIR reflectance of C4-3 are always greater than those of C4-2 due to the fact that chemical fertilizer of C4-3 is greater than that of C4-2. Obviously, there is strong relation between NIR reflectance and GM value as shown in Figure 8. Around 0.77 of R^2 value is confirmed between both.

Not only mean of NIR reflectance but also variance of NIR reflectance differs by small fields depending on the amount of nitrogen of chemical fertilizer.

3) Uniformity Evaluation with Radio Conrtrolled Helicopter Based NIR Camera: During the period from August 15 to September 24 2012, the rice crop fields are observed with radio controlled helicopter mounted NIR camera.

TABLE II. NIR REFLECTANCE AND GM VALUES MEASURED

	C4-2	C4-3	GM(C4-2)	GM(C4-3)
Aug.15	0.258	0.338	31	35.3
Aug.17	0.345	0.413	32.4	33.5
Aug.20	0.305	0.345		
Sep.7	0.324	0.485	42.4	44.1
Sep.24	0.413	0.547	38.8	45.7

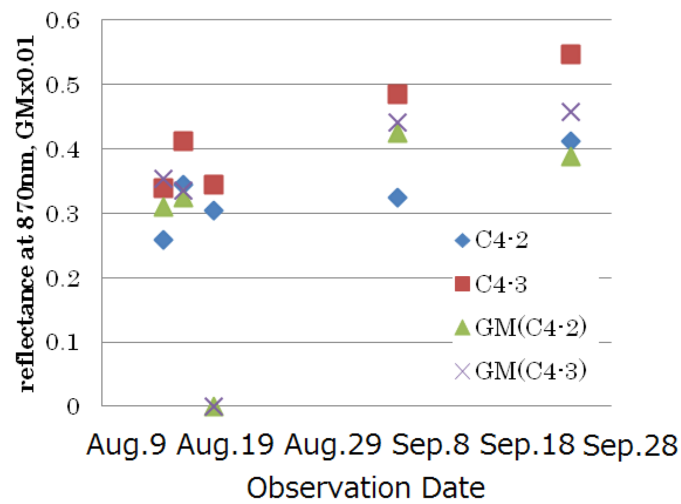


Fig. 7. NIR reflectance trend

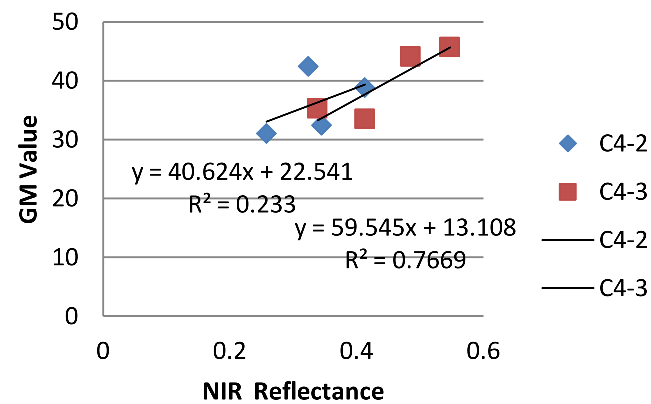
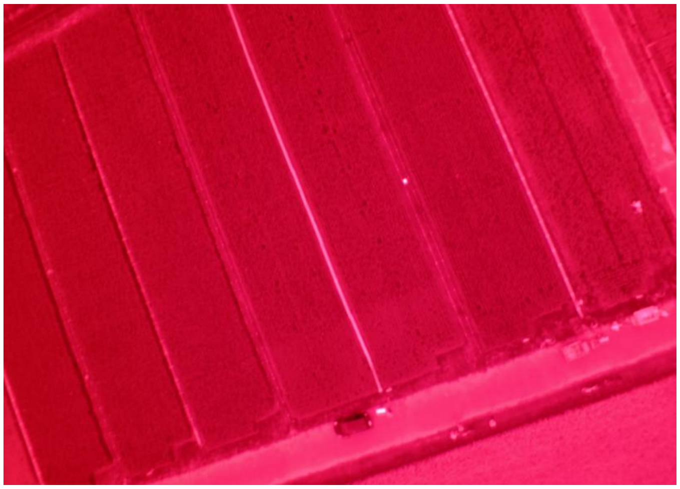


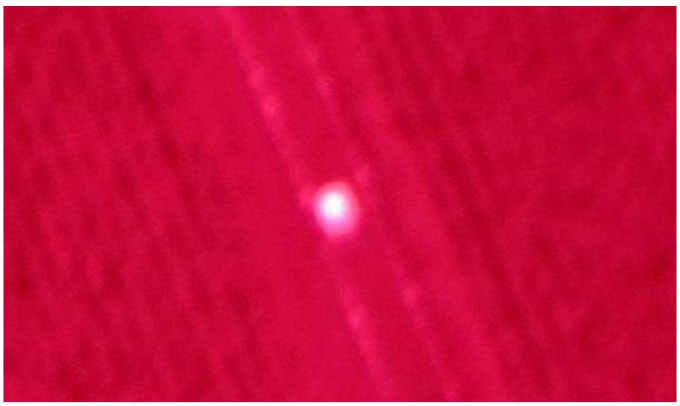
Fig. 8. Relation between GM value and NIR reflectance

Examples of the acquired images on September 28 are shown in Figure 9. C4-2 is situated on the right side of the photos while C4-3 is seen on the left hand side. In the middle of the photos, there is spectralon. It looks a small dots due to the fact that helicopter altitude is 30 m so that Instantaneous Field of View: IFOV is around 1.1 cm (Pixel size). Figure 9 (a) shows entire one shot of the acquired image with FOV of PowerShot of NIR camera while Figure 9 (b) shows enlarged portion of the acquired image. Meanwhile, Figure 9 (c) and (d) shows another shot of image at the different time on the same day. These show a good repeatability and reproduceability. NIR reflecttance can be calculated by taking the ratio of the pixels value of the fields and that of Spectralon.

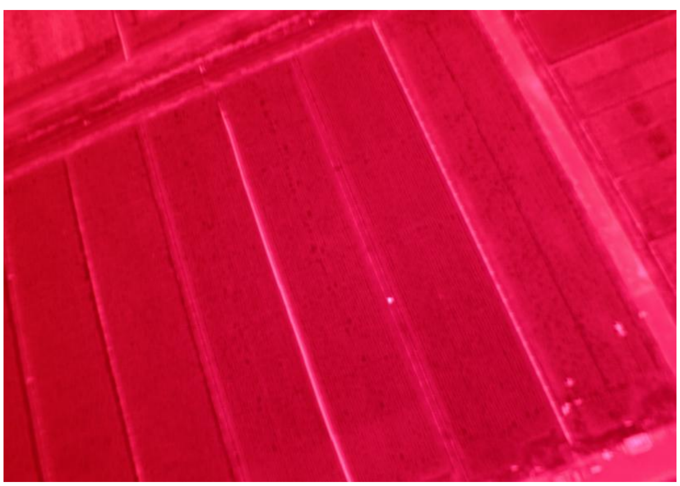
Uniformity in the small fields, C4-2, C4-3 are relatively good. Meanwhile, mean and variance are different by the samll fields due to the fact that the given chemical firtilizers are different each other small fields.



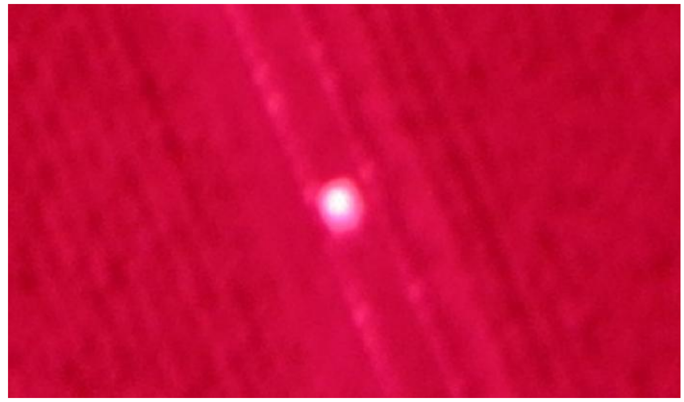
(a)Whole area of the Test site of C4-2 and C4-3



C4-2 (b)Enlarged image portion between C4-2 and C4-3 C4-3



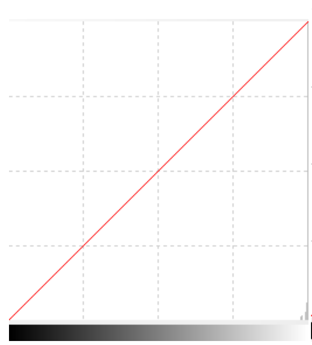
(c)Whole area of the Test site of C4-2 and C4-3

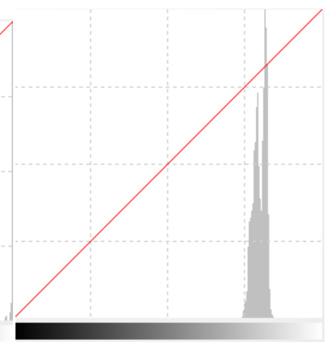


C4-2 (d)Enlarged image portion between C4-2 and C4-3 C4-3

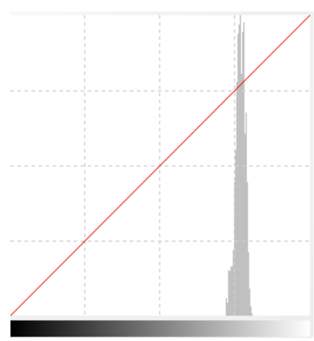
Fig. 9. Examples of the acquired images with radio controlled helicopter mounted NIR camera of PowerShot

4) Histogram of the Acquired Pixel Values of Spectralon and the Small Fields: Figure 10 shows the histograms of the acquired pixel values of C4-2 and C4-3 of small fields acquired at around 9:30 on September 28 2012, while Figure 11 shows those acquired at the different time (15 minutes after the acquisition of the previous scene) on September 28 2012.



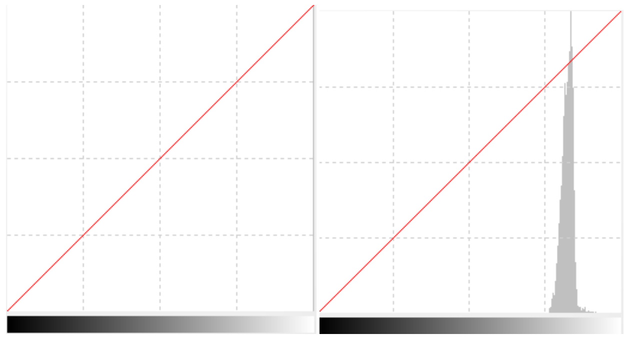


(a)Spectraron (b)C4-3: NIR Reflectance=0.787

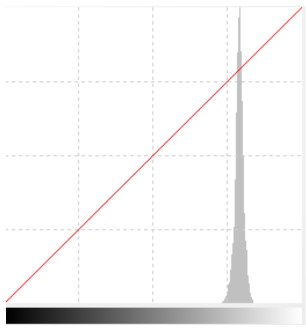


(c)C4-2: NIR Reflectance=0.765

Fig. 10. Histograms of the pixels in C4-2 and C4-3 acquired on September 24 2012.



(a)Spectralon (b)C4-3: NIR Reflectance=0.813



(c)C4-2: NIR Reflectance=0.787

Fig. 11. Histograms of the pixels in C4-2 and C4-3 small fields acquired on September 28 2012

5) Relation Between Nitrogen Content in the Rice Leaves and NIR Reflectance: Nitrogen content in the rice leaves is measured based on the Dumas method[8] (a kind of chemistry method) with Sumigraph NC-220F [9] of instrument. The measured total nitrogen content is compared to the NIR reflectance. Figure 12 and Table 3 shows the relation between the measured total nitrogen content and the measured NIR reflectance. Both show a good coincidence with not so large R^2 values around 0.25. There is a good correlation bteween rice crop quality and nitrogen content in the rice leaves. Therefore, it is confirmed that rice crop quality can be estimated with NIR reflectance measured with NIR cameras mounted on radio controlled helicopter.

IV. CONCLUSION

Rice crop field monitoring system with radio controlled helicopter based near infrared cameras is proposed together with nitrogen content estimation method for monitoring its distribution in the field in concern. Through experiments at the Saga Prefectural Agricultural Research Institute: SPARI, it is found that the proposed system works well for monitoring nitrogen content in the rice crop which indicates quality of the rice crop and its distribution in the field in concern. Therefore, it becomes available to maintain the rice crop fields in terms of quality control. It is fund that the relation between the measured total nitrogen content and the measured NIR reflectance. Both show a good coincidence with not so large R^2 values around 0.25. There is a good correlation between rice crop quality and nitrogen content in the rice leaves. Therefore, it is confirmed that rice crop quality can be estimated with NIR reflectance measured with NIR cameras mounted on radio controlled helicopter.

TABLE III. NIR REFLECTANCE AND NITROGEN CONTENT

Nitrogen Content (%)	NIR Reflectance
2.591256	0.8
2.573044	0.8375
2.401106	0.825
2.422404	0.82
1.90562	0.7375
2.2527	0.7625
2.600833	0.7625
2.583339	0.775
2.462955	0.7875
2.61153	0.8125
3.030643	0.8125
2.969303	0.8
2.857584	0.8
2.757784	0.795

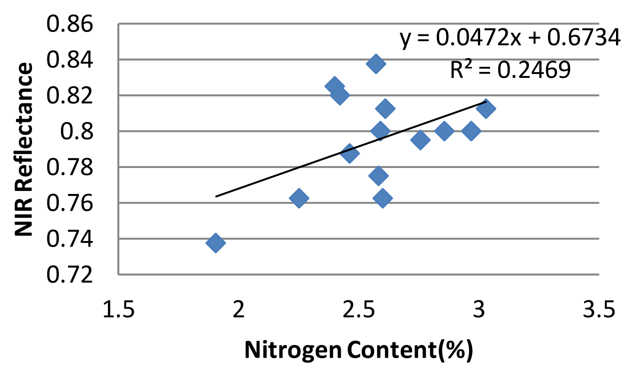


Fig. 12. Relation between nitrogen content in the rice leaves and NIR reflectance

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[1] J.T.Compton, Red and photographic infrared linear combinations for monitoring vegetation, Journal of Remote Sensing of Environment, 8, 127-150, 1979.

[2] C.Wiegand, M.Shibayama, and Y.Yamagata, Spectral observation for estimating the growth and yield of rice, Journal of Crop Science, 58, 4, 673-683, 1989.

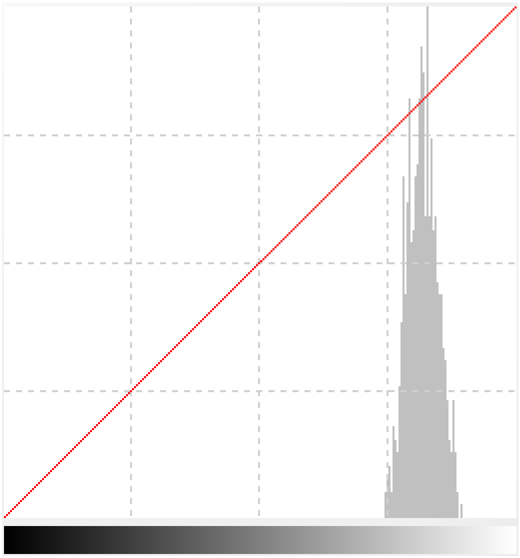
AUTHORS PROFILE

Kohei Arai, He received BS, MS and PhD degrees in 1972, 1974 and 1982, respectively. He was with The Institute for Industrial Science, and Technology of the University of Tokyo from 1974 to 1978 also was with National Space Development Agency of Japan (current JAXA) from 1979 to 1990. During from 1985 to 1987, he was with Canada Centre for Remote Sensing as a Post Doctoral Fellow of National Science and Engineering Research Council of Canada. He was appointed professor at Department of Information Science, Saga University in 1990. He was appointed councilor for

[8] http://note.chiebukuro.yahoo.co.jp/detail/n92075

[9] http://www.scas.co.jp/service/apparatus/elemental_analyzer/sumigraph_nc-220F.html

the Aeronautics and Space related to the Technology Committee of the Ministry of Science and Technology during from 1998 to 2000. He was also appointed councilor of Saga University from 2002 and 2003 followed by an executive councilor of the Remote Sensing Society of Japan for 2003 to 2005. He is an adjunct professor of University of Arizona, USA since 1998. He also was appointed vice chairman of the Commission "A" of ICSU/COSPAR in 2008. He wrote 30 books and published 332 journal papers



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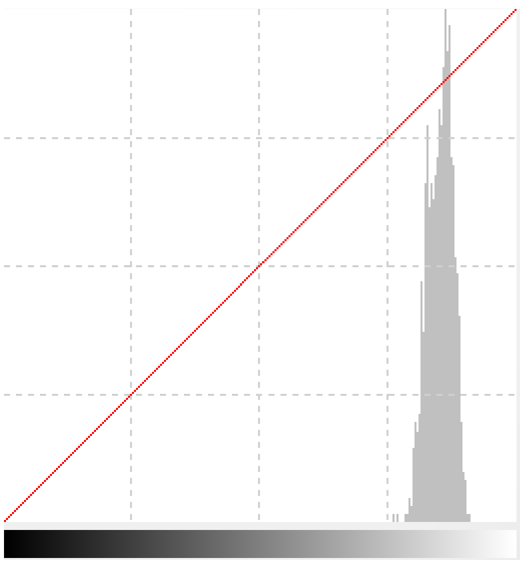

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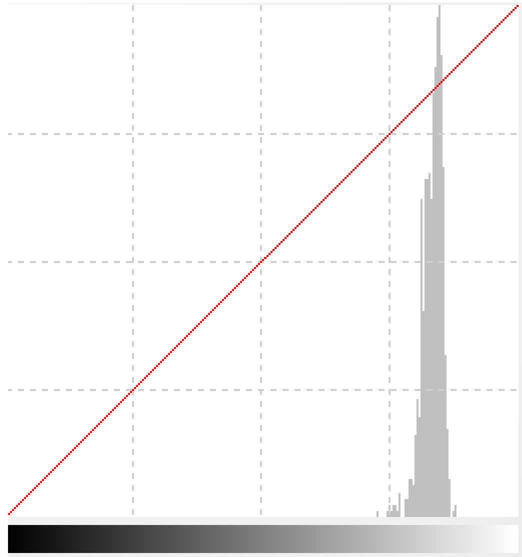

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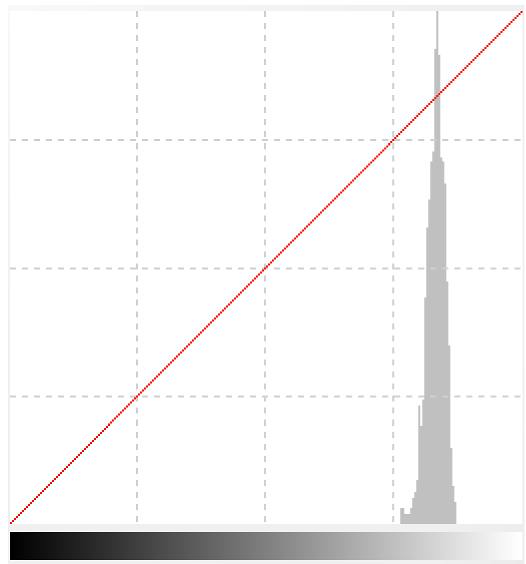

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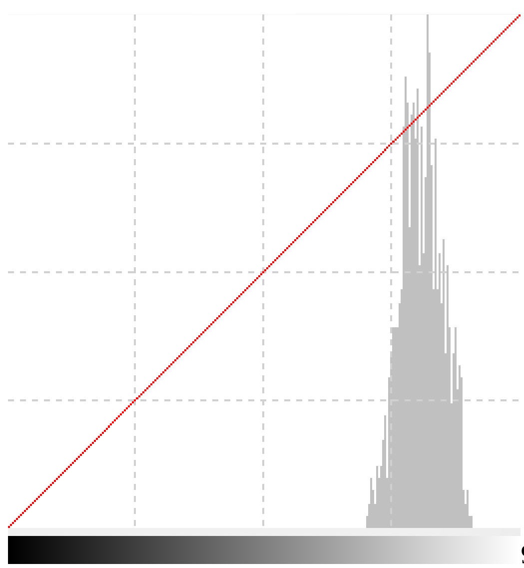

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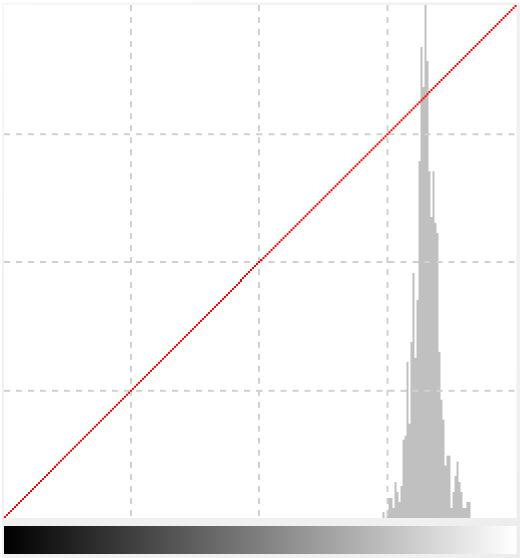

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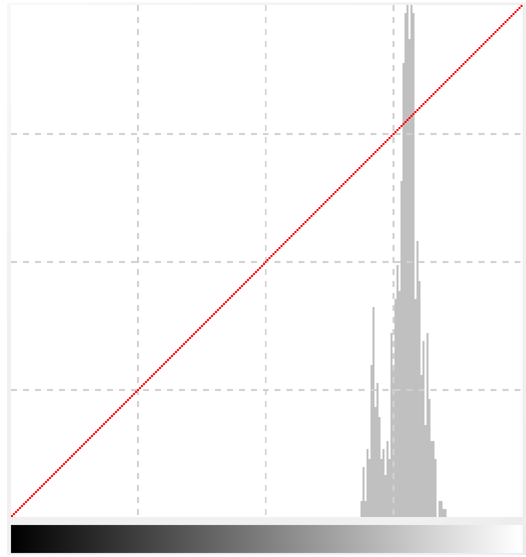

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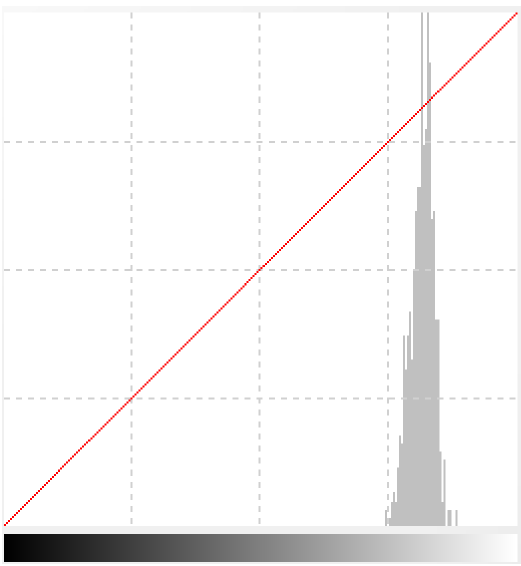

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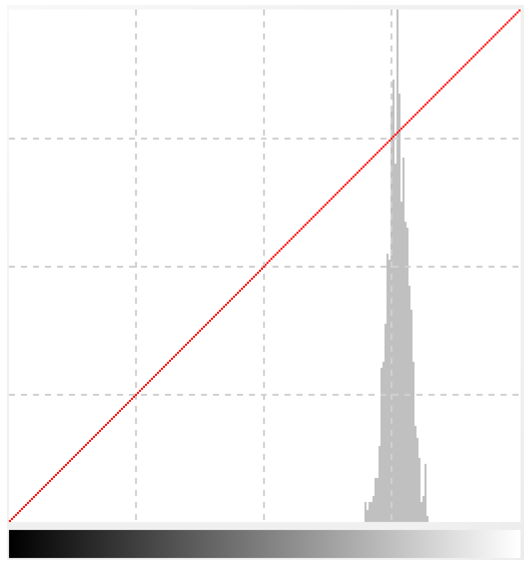

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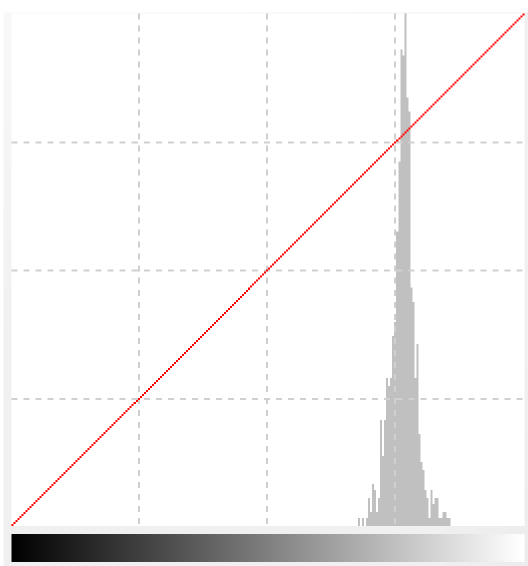

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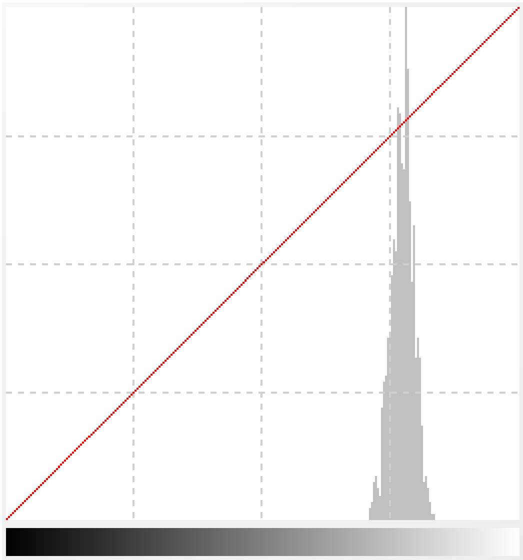

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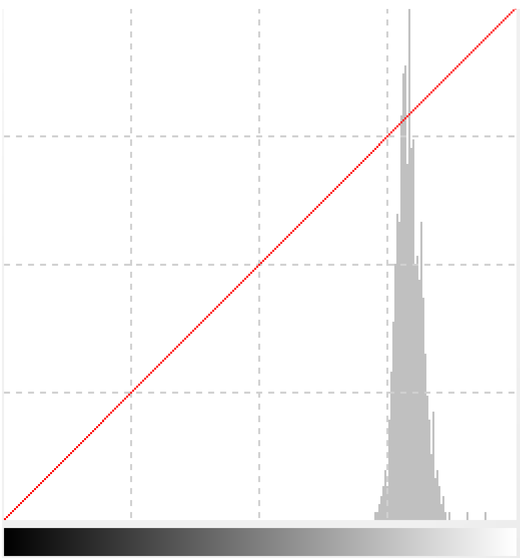

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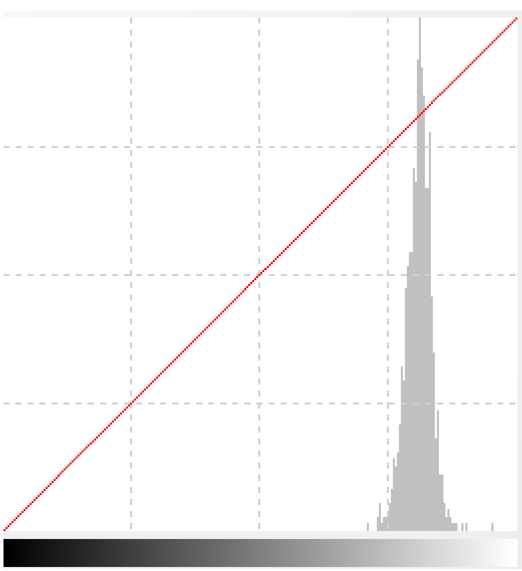

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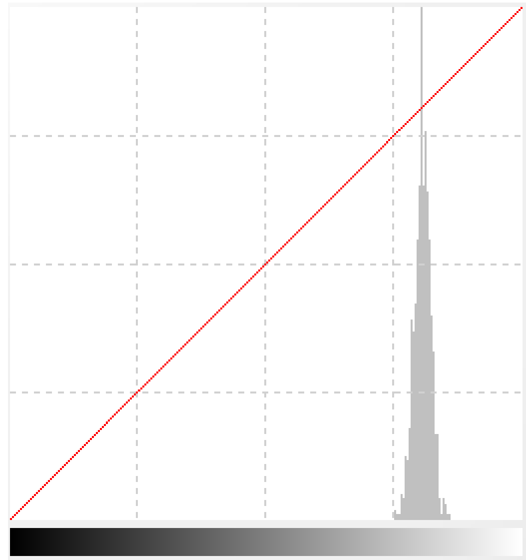

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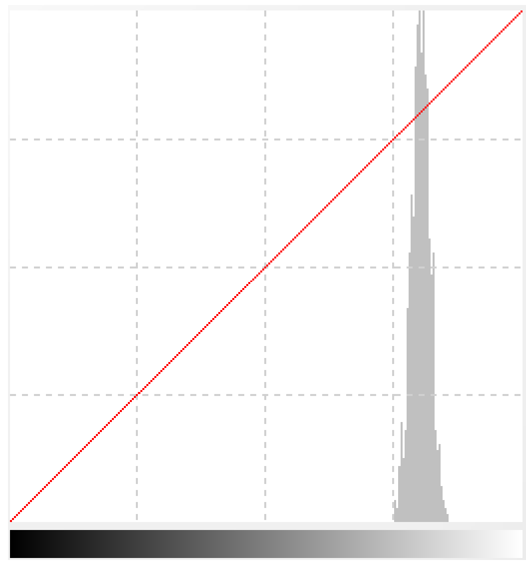

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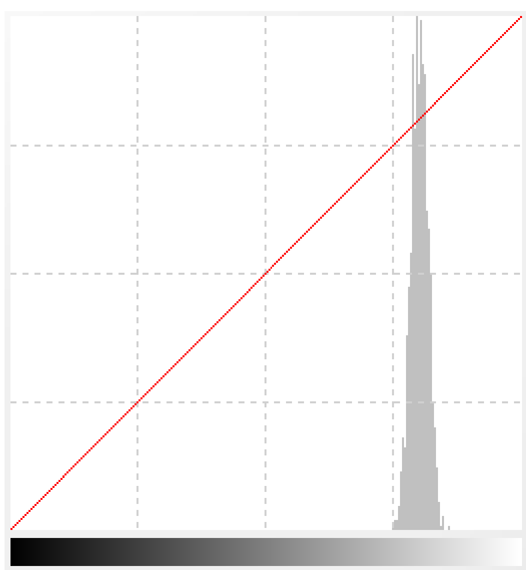

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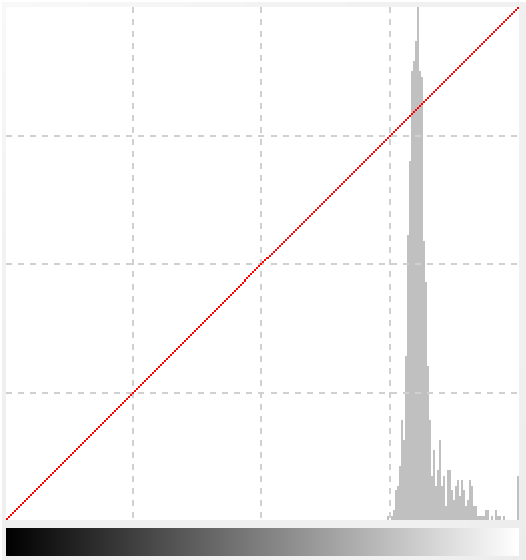

10

Regressive Analysis on Leaf Nitrogen Content and Near Infrared Reflectance and Its Application for Agricultural Farm Monitoring with Helicopter Mounted Near Infrared Camera

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***Abstract*—Method for evaluation of nitrogen richness of tealeaves with near infrared reflectance is proposed. Also tea farm monitoring with helicopter mounted near infrared camera is proposed. Through experiments and regressive analysis, it is found that the proposed method and monitoring system is validated.**

Keywords-regressive analysis; nitrogen content; tealeaves; near infrared cameras; t

I. Introduction

Vitality monitoring of vegetation is attempted with photographic cameras [1]. Grow rate monitoring is also attempted with spectral reflectance measurements [2]. Total nitrogen content corresponds to amid acid which is highly correlated to Theanine: 2-Amino-4-(ethylcarbamoyl) butyric acid so that total nitrogen can be used for a measure of the quality of tealeaves.

It is well known that Theanine rich tealeaves taste good while fiber content in tealeaves is highly correlated to the grow rate of tealeaves. Both total nitrogen and fiber content in tealeaves are highly correlated to the reflectance in the visible and Near Infrared: NIR wavelength regions and vegetation index derived from visible and NIR data so that it is possible to determine most appropriate tealeaf harvest date using the total nitrogen and fiber content in the tealeaves which are monitored with ground based visible and NIR cameras and with Helicopter mounted NIR cameras.

It is obvious that nitrogen rich tealeaves tastes good while fiber rich tealeaves tastes bad. Theanine: 2-Amino-4-(ethylcarbamoyl) butyric acid that is highly correlated to nitrogen contents in new tealeaves are changed to catechin [3],[4],[5] due to sun light. In accordance with sun light, new tealeaves grow up so that there is a most appropriate time for harvest in order to maximize amount and taste of new tealeaves simultaneously.

Regressive analysis is conducted with measured total nitrogen and NIR reflectance measured with ground based spectral radiometer and helicopter mounted NIR camera data. Both total nitrogen contents and NIR reflectance derived from ground based and helicopter mounted NIR camera shows a good coincidence. Therefore, it is concluded that the proposed method and monitoring system is validated and appropriate.

The following section describes the proposed method and monitoring system for estimation of total nitrogen content and followed by some experiments. Then conclusion is described together with some discussions.

II. Proposed Method

A. Regressive Analysis

Linear regressive equation is expressed in equation (1).

$$N = a R + b \qquad (1)$$

where N, R denotes measured Nitrogen content in leaves, and measured Near Infrared: NIR reflectance, respectively while a and b denotes regressive coefficients. There is well known relation between nitrogen content and NIR reflectance. Therefore, regressive analysis based on equation (1) is appropriate.

B. Proposed Method for Tealeaves Quality Evaluation of

Tealeaves quality can be represented Theanine content which is closely related to nitrogen content. Furthermore, it is well known that nitrogen content can be represented with NIR reflectance. Therefore, tealeaves quality can be evaluated with measured NIR reflectance based on the equation (1).

The proposed method and tea farm area monitoring system with helicopter mounted NIR camera is based on the aforementioned scientific background.

C. Tea Farm Area Monitoring System with Helicopter Mounted NIR Cameras

The helicopter used for the proposed system is "GrassHOPPER" manufactured by Information & Science Techno-Systems Co. Ltd. Outlook of helicopter is shown in Figure 1. Table 1 shows major specification of GrassHOPPER.

Fig. 1. Outlook Of The Grasshopper

TABLE I. MAJOR SPECIFICATION OF GRASSHOPPER

weight	2kg（Helicopter only）
size	80cm × 80cm × 30m
payload	600g

Canon Powershot S100（focal length=24mm）is mounted on the GrassHOPPER. It allows acquire images with the following Instantaneous Field of View: IFOV at the certain altitudes, 1.1cm (Altitude=30m）3.3cm (Altitude=100m）and 5.5cm（Altitude=150m）.

In order to measure NIR reflectance, standard plaque whose reflectance is known is required. Spectralon provided by Labsphere Co. Ltd. is well known as well qualified standard plaque. It is not so cheap that photo print papers are used for the proposed system. Therefore, comparative study is needed between Spectralon and the photo print papers.

The proposed system consist Helicopter, NIR camera, photo print paper. Namely, photo print paper is put on the agricultural plantations, tea trees in this case. Then farm areas are observed with helicopter mounted NIR camera. Nitrogen content in agricultural plants, tealeaves in this case, is estimated with NIR reflectance.

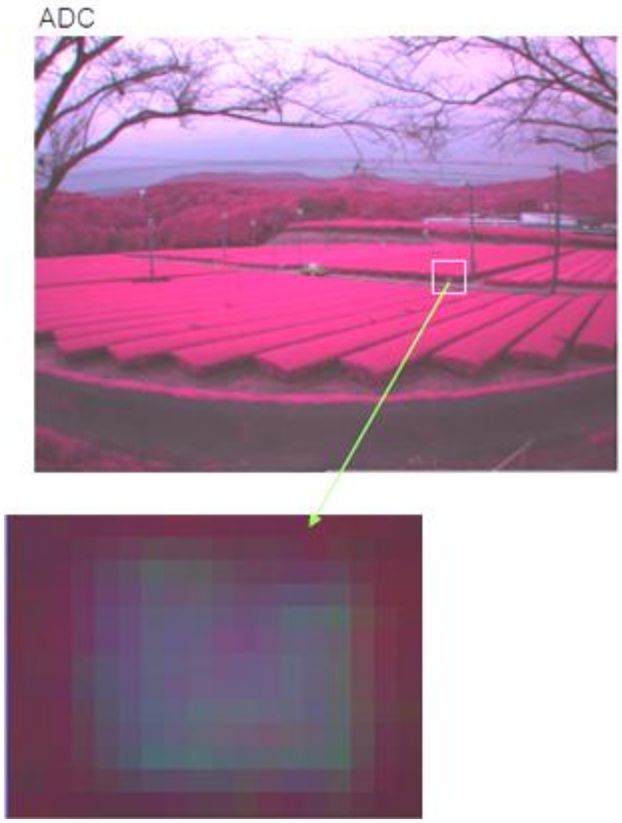
III. EXPERIMENTS

A. Preliminary Experiments

There are some candidates of NIR Cameras, Ricoh GX200, Cannon PowerShot S100, ADC3 which allows not only NIR image but also Normalized Deviation of Vegetation Index: NDVI iamge, etc. Before acquiring NIR reflectance data with helicopter mounted NIR cameras, ground surface images are acquired with the candidate ground based cameras. Figure 2(a) and (b) shows examples of the acquired images with Ricoh GX200 and ADC3, respectively. Although Ricoh GX200 is just a visible camera, NIR image is also acquired with the camera if NIR filter is attached to the optical entrance of the camera. On the other hand, ADC3 has NIR channel. Therefore, NIR image is acquired as shown in Figure 2 (b).

From the acquired images of Figure 2, a small portion of image is extracted and enlarged as shown in the bottom image of Figure 2 (a) and (b). In the portion of image, there is name board of tealeaves.

(a)Ricoh GX200



(b)ADC3

Fig. 2. Examples of the acquired images with Ricoh GX200 and ADC3

The name board of Figure 2 (a) is much clear than that of Figure 2 (b). Tea farm area is designated at Prefectural Tea Institute which is situated in Ureshino city, Saga, Japan. Preliminary tests are conducted for confirmation of the relation between helicopter altitude and IFOV with GrassHOPPER and ADC3. An example of acquired image is shown in Figure 3. Also, Figure 4 shows examples of images which are acquired with GrassHOPPER mounted ADC3 camera with the different altitudes.

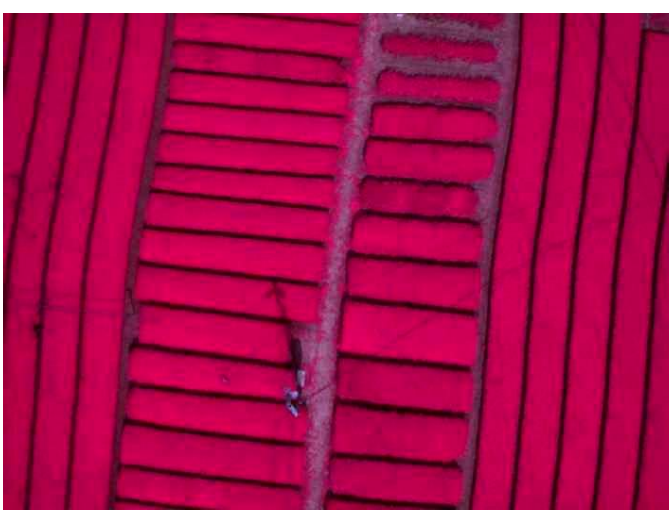
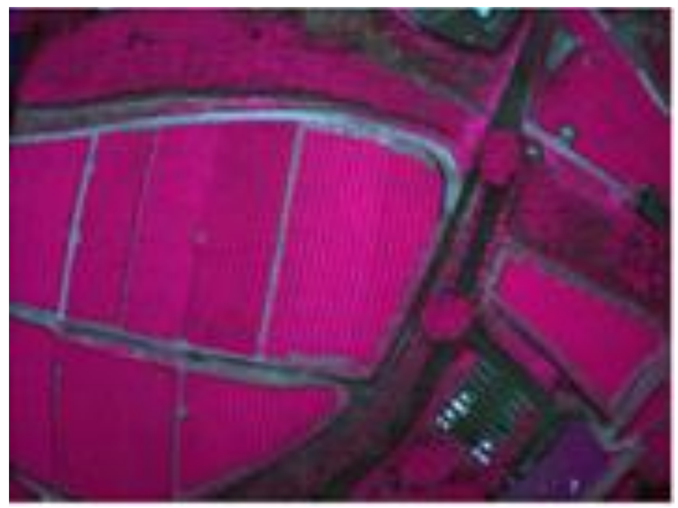


Fig. 3. Example of acquired image with GrassHOPPER mounted ADC3 camera.

(a)h=30m, IFOV=2.5cm



(b)h=100m, IFOV=8cm

(c)h=150m, IFOV=12cm

Fig. 4. Examples of acquired image with the different altitudes

Figure 4 (a) shows the acquired image at the helicopter altitude of 30m while Figure 4 (b) shows that at 100m. Figure 4 (c) shows the image at the helicopter altitude of 150m.

Due to the fact that standard plaque is required for estimation of NIR reflectance, and Field of View of the Cameras is limited, not so small number of standard plaques is required for the wide areas of tea farm area and agricultural farm areas. Therefore, relatively cheap photo print papers are used as standard plaque. Through a comparison between well qualified standard plaque of Spectralon and the proposed photo print papers, usability of the photo print papers is confirmed as a standard plaque.

Figure 5 shows example of acquired image with GrassHOPPER mounted ADC3 camera. Standard plaque has to be acquired within a range of Field of View of the camera. Green rectangle shows four shots of acquired image with the camera (ADC3) from the 50 m of altitude.

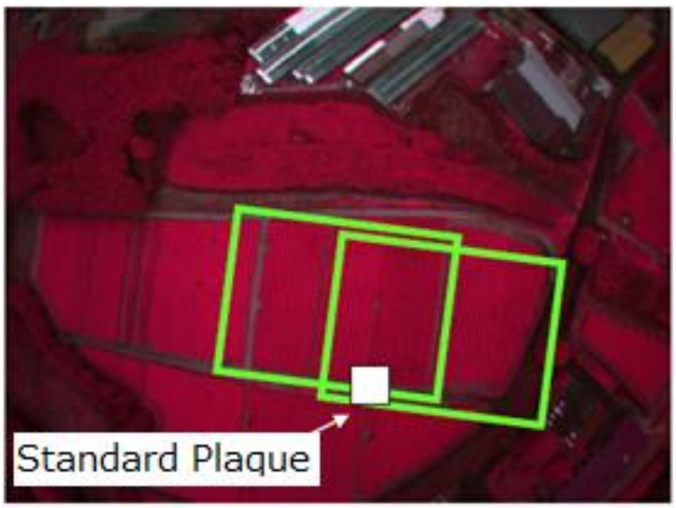


Fig. 5. Example of the acquired image with GrassHOPPER mounted ADC3 camera.

Figure 6 (a) shows outlook of the tea farm area while Figure 6 (b) shows Spectralon of standard plaque and photo print paper (Both are aligned together closely) which are put on the tea trees. Also Figure 7 shows rectified three strips of GrassHOPPER tranck. In the first strip, standard plaque and photo print paper can be seen in the acquired image.

(a)Tea farm area

(b)Spectralon and photo print paper

Fig. 6. Outlook of the tea farm area and Spectralon of standard plaque and photo print paper which are put on the tea trees

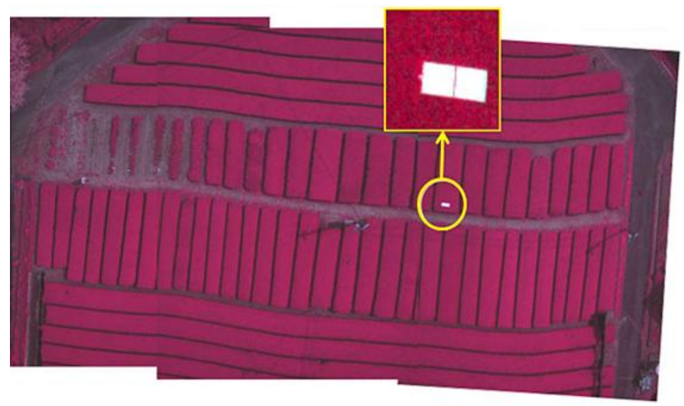


Fig. 7. Rectified three strips of GrassHOPPER tranck.

As the results, it would be better to put photo print papers in all strips of GrassHOPPER traks. Then NIR reflectance can be estimated with a reference to the pixel value of the photo print paper in the image in the corresponding strip.

B. Comparison Between GrassHOPPER Mounted ADC3 Acquired Reflectance and Measured Reflectance with Ground Based MS-720 of Spectral Radiometer

A comparison between GrassHOPPER mounted ADC3 acquired reflectance and measured reflectance with ground based MS-720 of spectral radiometer manufactured by Eiko Co. Ltd., Japan is conducted. MS-720 is reliable radiometer with 5nm of wavelength resolution. This experiment is conducted at Saga Prefectural Tea Experiment Station of Ureshino City, Saga Japan, on April 9 2012.

By comparing between the reflected radiance from the Spectralon and the reflected radiance from the tealeaves, the reflectance can be measure. On the other hand, GrassHOPPER mounted ADC3 derived reflectance is estimated by comparing the pixel values of the Spectralon image portion and that of the tealeaves of image portion. Table 2 shows the average and the standard deviation of GrassHOPPER mounted ADC3 derived reflectance and ground based MS-720 derived reflectance. Both show a good coincidence between mean values as shown in Figure 8. The horizontal axis of Figure 8 is GrassHOPPER mounted ADC3 derived reflectance while the vertical axis is ground based MS-720 derived reflectance.

TABLE II. MEAN AND STANDARD DEVIATION OF NIR REFLECTANCE MEASURED WITH GRASSHOPPER MOUNTED ADC3 AND GROUND BSED MS-720 OF STECTRAL RADIOMETER

	GrassHOPPER	MS-720
Mean	0.451	0.421
Standard Deviation	0.0428	0.0325

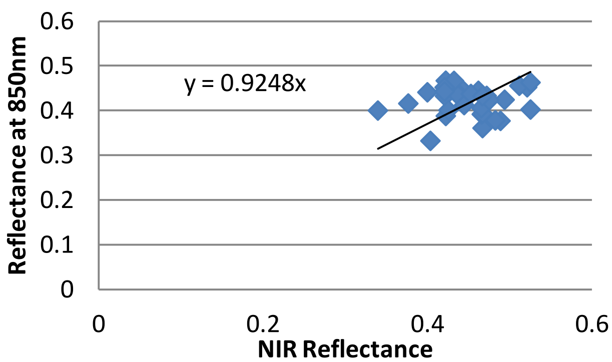


Fig. 8. Relation between GrassHOPPER mounted ADC3 derived reflectance and ground based MS-720 derived reflectance.

The NIR reflectance (which is proportional to total nitrogen content and Theanine of amino acid in the tealeaves) is increasing in accordance with tealeaves grow as shown in Table 3 and Figure 9.

TABLE III. TABLE TYPE STYLES

	9 April	23 April
Mean	0.497	0.622
Standard Deviation	0.0548	0.0539

Horizontal and vertical axis of Figure 9 shows different species and NIR reflectance, respectively. On the other hand, Blue, Red, and Green colored bar denotes, NIR reflectance which is measured on April 9, 10, and 23, respectively. Most of species of tea trees are grown up during this period and are harvested in the begging of May.

Total nitrogen content of the tealeaves is measured based on Kjeldahl method (a kind of chemistry method). The measured total nitrogen content is compared to the NIR reflectance. Figure 10 shows the relation between the measured total nitrogen content and the measured NIR reflectance. Both show a good coincidence.

As aforementioned, the pixels for standard plaque in the helicopter strip image are required for estimation of NIR reflectance. FOV of the helicopter mounted NIR cameras are limited. Therefore, not so small number of helicopter strips which is corresponding to the number of standard plaques are required for cover the entire tea farm areas.

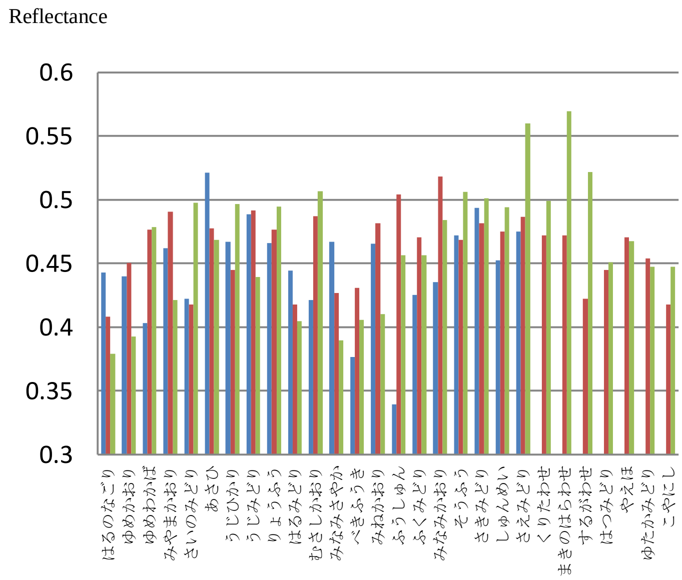


Fig. 9. NIR reflectance trend from April 9 to 23 2012.

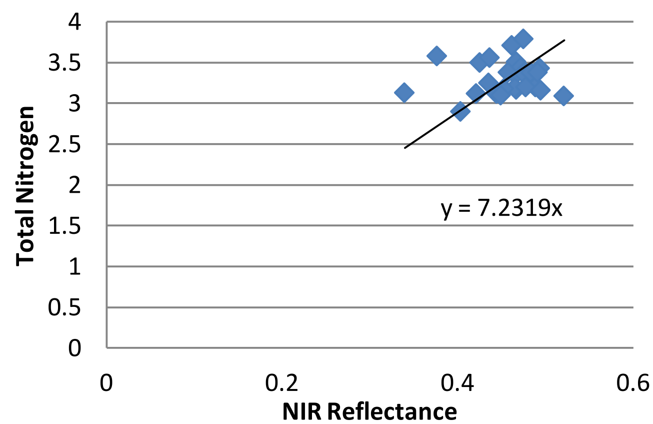


Fig. 10. Shows the relation between the measured total nitrogen content and the measured NIR reflectance

Then relatively cheap photo print paper is used on behalf of Spectralon of standard plaque. Therefore, it would be better to compare the mean and standard deviation of measured NIR reflectance between standard plaque and photo print paper. Table 4 shows the comparison between both.

TABLE IV. COMPARISON OF THE MEAN AND STANDARD DEVIATION OF MEASURED NIR REFLECTANCE BETWEEN STANDARD PLAQUE AND PHOTO PRINT PAPER.

	Standard Plaque	Photo Print Paper
Mean	0.465	0.484
Standard Deviation	0.0484	0.0503

The mean of the NIR reflectance which is measured with photo print paper is a little bit greater than that with standard plaque while the standard deviation of the NIR reflectance which is measured with photo print paper is a little bit greater than that with standard plaque.

NIR reflectance measurement experiments are conducted at Saga Prefectural Tea Experiment Station, Ureshino, Saga, Japan during from April 9 to April 23 2012. During the period, 8 times measurement data are obtained. Figure 11 shows the trend of NIR reflectance at the period.

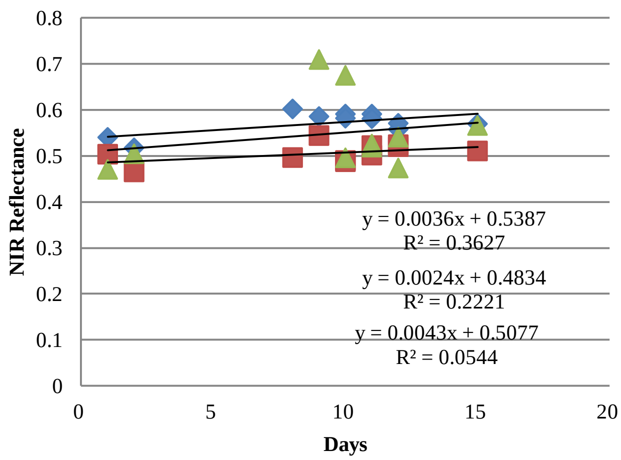


Fig. 11. Trend of NIR reflectance for the period starting from April 9 to April 23.

During this period, measured NIR reflectance is increasing in accordance with the time duration. Black solid lines show linear approximated lines for the different species of tealeaves. Variability of the NIR reflectance may be caused by the weather condition (Illumination, waving tealeaves due to the wind, influence due to shadow and shade, etc.).

IV. CONCLUSION

Method for evaluation of nitrogen richness of tealeaves with near infrared reflectance is proposed. Also tea farm monitoring with helicopter mounted near infrared camera is proposed. Through experiments and regressive analysis, it is found that the proposed method and monitoring system is validated.

In particular, relation between measured NIR reflectance and total nitrogen content is clarified. Also it is found that photo print paper can be used as the reference target for estimation of NIR reflectance.

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A Knowledge-Based System Approach for Extracting Abstractions from Service Oriented Architecture Artifacts

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***Abstract*—Rule-based methods have traditionally been applied to develop knowledge-based systems that replicate expert performance on a deep but narrow problem domain. Knowledge engineers capture expert knowledge and encode it as a set of rules for automating the expert's reasoning process to solve problems in a variety of domains. We describe the development of a knowledge-based system approach to enhance program comprehension of Service Oriented Architecture (SOA) software. Our approach uses rule-based methods to automate the analysis of the set of artifacts involved in building and deploying a SOA composite application. The rules codify expert knowledge to abstract information from these artifacts to facilitate program comprehension and thus assist Software Engineers as they perform system maintenance activities. A main advantage of the knowledge-based approach is its adaptability to the heterogeneous and dynamically evolving nature of SOA environments.**

Keywords—expertise; rule-based system; knowledge-based system; service oriented architecture; SOA; software maintenance; search tool.

I. SOA, Maintenance And The Role Of Expertise

Rule-based methods have been very effective in supporting decision making in many complex domains. Can they also assist Software Engineers in dealing with the emerging complexities of Service Oriented Architecture (SOA) applications?

SOA is not a single software architecture, but rather a style for constructing complex systems, especially those that need to cross organizational boundaries. SOA systems, often called *composite applications*, typically resemble Fig. 1.

An organization, whether governmental, non-profit, or private, finds that it needs to work with other organizations to carry out key workflows.

For example fulfilling a purchase order requires getting stock from a partner company, planning employee travel involves reservations on several airlines, or providing a doctor with a patient's medical history entails assembling information from many medical records systems.

As shown in Fig. 1, in a SOA architecture the software to support these workflows is organized as *services* having defined interfaces, running on different nodes and communicating via message passing. Some of these services will be owned and managed by the home organization but others will belong to partners or be offered by commercial vendors.

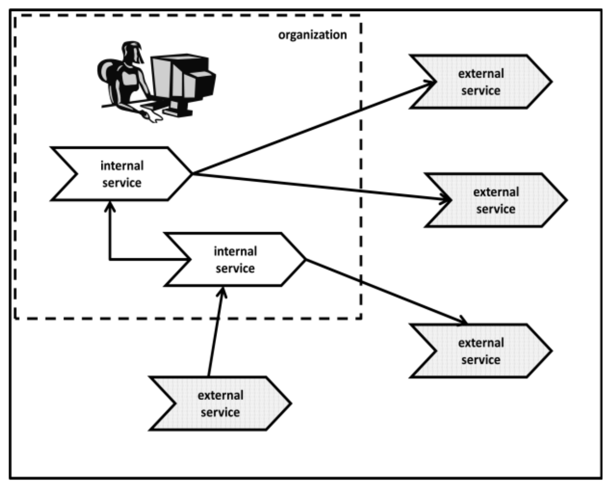

Fig. 1. A SOA Composite Application

Most commonly the Web Services group of standards is used to define the service interfaces and protocols [1]. In theory, these standards are supported by a broad group of providers so that services can interoperate across many different programming languages, operating systems, and data definition schemas. However, the standards have turned out to be both very complex and very loose, leading different implementers to create services and interfaces having vastly different styles.

SOA composite applications began to appear at the start of the twenty first century and by now are very widespread. They have faced many technical and managerial difficulties, but perhaps none will be more difficult than the challenge of *software maintenance* as these systems begin to age. Traditionally, maintenance of large software applications has been particularly expensive and slow because typically:

a) There is a large code base of existing, legacy software.

b) To make changes safely, scarce and expensive Software Engineering personnel must first invest time to understand that existing software.

c) Turnover of such personnel leads to loss of human knowledge and the application gradually slides into a state sometimes called "servicing" in which only very limited changes may be safely attempted [2].

The essential reason for the cost and delays of software maintenance is thus the difficulty of acquiring and sustaining necessary Software Engineering expertise. As several authors have pointed out, sustaining that expertise for SOA may be even harder than with earlier application styles [3] [4] [5] [6] [7] [8]. The challenges include:

1) The heterogeneity of SOA applications, so that maintainers may need expertise in many different languages, environments, and implementation styles.

2) The distributed ownership of services, so that for business reasons source code or key documents may not be made available to the maintainers.

3) Poorly coordinated changes, as the different service owners are driven by different business needs, leading to crises and to multiple fielded versions of each service.

SOA Software Engineers will thus have to respond to continual and often unpredictable change as they maintain large heterogeneous applications exhibiting a bewildering variety of programming styles. This research explores how knowledge-based methods can help provide the necessary expertise to help SOA systems evolve at reasonable cost.

In this paper we describe a knowledge-based approach to this problem, in which a rule-based system is used to enhance search techniques so that a Software Engineer can more rapidly understand a given composite application. The rule-based system generates *abstractions*, snippets of information that summarize complex application relationships to provide context quickly. The main benefit of the rule-based method is adaptability; different application styles and changing environments may be handled by relatively simple modifications to the rules. Thus a rule set can itself dynamically evolve as the composite application evolves to meet changing needs.

In the next section the article reviews related work followed by a presentation of an illustrative example to motivate the need for SOA abstractions. Then it describes the design principles appropriate for search in a SOA context, discusses the knowledge-based approach to SOA abstraction, and presents the results of an evaluation case study. The article concludes with a summary of key contributions and suggestions for future work.

II. RELATED WORK

Although little literature is available regarding the use of rule-based systems for SOA system maintenance, rule-based systems have been applied more broadly to software understanding. Canfora and Di Penta [4] describe two tools, Design Maintenance System [9] and TXL [10] which parse source code and, through rule-based transformations, produce artifacts that facilitate program understanding. Braun [11] describes a server-based analysis system based upon rules that is designed to play a role in configuration management of software. The idea is that checked-out versions can be subjected to rule-based checks for various attributes before they are committed to a version control system.

Rule-based information extraction akin to the idea of summarizing software abstractions in the current work appears to be an area of increasing interest. Zaghouani [12] describes a system for named entity extraction from text in natural language processing. Wang [13] describes named entity extraction with rules and a machine learning approach using "conditional random fields." Michelakis et al. [14] describes rule-based information extraction in which structured objects are extracted from text, based on user-defined rules.

Research on tools to support maintenance of SOA systems has been fairly limited. Most of the proposals involve dynamic analysis, usually of a trace from a running system. A group from IBM has described a tool called Web Services Navigator that uses dynamic analysis to provide five different views of an executing system [15]. Two papers describe ways of locating user features within a SOA system. One approach produces a sequence diagram showing the feature [16] while the other does an analysis of dynamic call trees [17]. Halle et al. have a somewhat different approach that starts from a hypothesized service contract and automatically sends a series of trial invocations to see if the service actually conforms to the hypothesis [18]. Dynamic analysis is a powerful approach to understanding a system; the main difficulty is that it is frequently impractical to gather the needed data from a large system running across multiple nodes.

III. SOA MAINTENANCE CHALLENGES: AN ILLUSTRATIVE EXAMPLE

To illustrate the problem of understanding SOA, consider an example from WebAutoParts.com, one of the composite applications in our Open SOALab collection of resources for SOA teaching and research [19]. WebAutoParts.com (Fig. 2) is a hypothetical online automobile parts supplier that uses external services to facilitate agile development. As is true for many SOA composite applications that are based on the Web Services standards, the main artifacts that describe WebAutoParts are BPEL program code, WSDL service interface descriptions and XSD data type definitions.

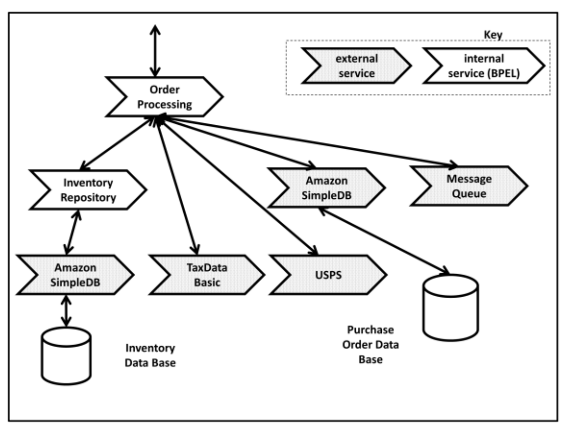

Fig. 2. Webautoparts.Com - Order Processing Workflow

BPEL, the Business Process Execution Language, is an XML formatted language that describes how services are orchestrated together to perform a complete workflow [20]. Each BPEL program itself becomes a service when it is interpreted on an application server. WSDL stands for Web Services Description Language [21]. WSDL files, which again have an XML format, describe the interface that a service presents to its clients. XML Schema Descriptions (XSDs) are an XML language used to describe the data types for the message data that is passed between services [22]. The data type descriptions for a particular service may either be incorporated into the <types> section of the service's WSDL file or else included from an external XSD file.

WebAutoParts has an order processing workflow shown in Fig. 2. There are two "stubbed" in-house services written in BPEL (Order Processing and Inventory Repository) and four external services from three well-known vendors:

- Amazon Web Services **-** *Amazon Simple DB* (database) and *Message Queue* (message queuing)
- StrikeIron.com **-** *Tax Data Basic* (sales tax rates)
- Ecocoma **-** *USPS* (shipping costs)

In this workflow, an incoming order is first checked against inventory to confirm that it can be processed. Then sales tax is computed based on the rules of the state where the customer resides. Shipping costs are then computed and added and finally the order is added to a message queue to be picked up by the order fulfillment service. While the WebAutoParts application does not actually execute, it consists of syntactically correct BPEL code which deploys successfully to the Ode BPEL environment along with XSD and WSDL documents typical of current industrial practice.

Suppose a Software Engineer unfamiliar with this application is trying to implement a change to the database design and needs to know what data is passed when Order Processing checks inventory levels. If he has extensive BPEL/Web Services experience he might figure this out using a series of searches (Fig. 3). In these searches he must match the names appearing in different XML elements and navigate up and down the containment hierarchy of these elements:

1) Search the Order Processing BPEL file to find the <invoke> tag that is checking inventory. That provides him a partnerLink. Then search the partnerLinks to get the partnerLinkType which turns out to be IRepositoryLinkType.

2) However, there is no indication of which service implements this link type, so the Software Engineer now searches all the WSDL documents for that link type. He will find it in InventoryRepository Artifacts.wsdl with a pointer to the WSDL portType for the service. The portType in turn gives the operation and its input and output message names. A further search on the message name reveals that the message contains an element called inventoryQuery.

3) *However inventoryQuery is not defined within the WSDL so the Software Engineer now has to search XSDs to eventually locate the definition of inventoryQuery, determine its type, and from its type finally conclude what data fields are being passed.*

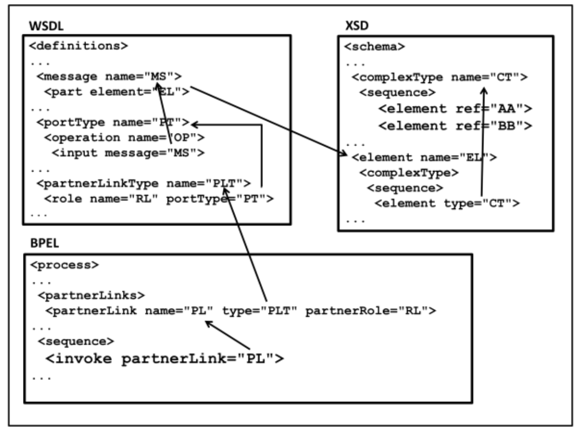

Fig. 3. Searching BPEL, Wsdls And Xsds

Even for a Software Engineer who is an expert in Web Services, tracing such chains of relationships requires a tedious and error-prone sequence of searches. Furthermore, the heterogeneity of SOA services will mean that expertise may not generalize well from one composite application to another. Each such application may use a different combination of technologies and apply them in different ways. There are, for example, many textually different ways to describe essentially the same message data using WSDLs and XSDs. Worse, the Web Services standards themselves are evolving so it is likely that a maintainer will encounter fielded systems based on different versions. Finally, since the WSDLs, XSDs, and configuration files that describe a composite application are often machine-generated, they contain "clichés" or patterns that are peculiar to a particular development environment. For example, an XSD generated by Microsoft's WCF framework contains five-tag sequences of XML to simply declare a void return type for an operation [23].

There is a lot of information contained in the artifacts describing a SOA composite application. Experts with long application-specific experience may be able to navigate these artifacts, but such experts will be scarce. Thus, the focus of this research is to develop a rule-based system that mimics expert reasoning on the SOA artifacts to provide useful information for a wider range of Software Engineers lacking specific knowledge in handling the artifacts.

IV. INTELLIGENT SEARCH FOR SOA MAINTENANCE

Intelligent search tools can help users find the kinds of information in SOA composites that maintainers may need. Search tools based on text matching are usable on a variety of document types making them a good fit for the heterogeneous world of SOA composite applications. Our group has been conducting research on the application of intelligent search for SOA maintenance using `SOAMiner`, a prototype SOA-specific search engine. Case studies with different groups of academic and real-world programmers have been exploring "what SOA maintainers will want to know" [23] [24].

The results of these studies have shown that participants found it easy and natural to search a large corpus of artifacts from a SOA composite application. They quickly found relevant snippets of information, such as all the XML tags containing a keyword such as "inventory". However search identified each snippet in isolation and did not show its context within the application as a whole. In some cases it was sufficient to simply show more of the surrounding text, but it is clear that for other problems a Software Engineer would need to make a tedious sequence of searches such as those in the example given earlier.

We conclude that, for SOA, search needs to be enhanced with a process of abstraction. For example, a search should take the user to relevant fragments of a BPEL, WSDL or XSD, and then provide a higher-level abstraction that shows how that fragment fits into a wider reality. A difficulty, of course, is that in SOA's open environment the relevant abstractions will vary from system to system and over time as standards, practices, and tools change.

Thus we need an adaptive and dynamic abstraction mechanism to complement SOA search. An ideal tool would index the collection of artifacts from a composite application and:

1) *Provide abstraction-enhanced search where it can.*
2) *Provide useful text-based search where it cannot.*
3) *Allow the definition of additional abstractions so that more and more searches can be moved into the first category.*

Such a tool should be flexible to adapt to a wide range of SOA artifacts from different environments and allow for the inclusion of new abstractions as they are discovered.

V. A Knowledge-based System for SOA Abstraction

Knowledge plays a key role in achieving intelligent behavior. Knowledge-based systems capture human knowledge, represent it in a machine readable form, and facilitate reasoning with it for solving problems. The following describes our approach to capture human expertise in SOA code analysis and to use that expertise for analyzing SOA artifacts and providing intelligent search support.

A. Rationale for Using a Rule-Based System

Rule-based systems have traditionally been used to capture human expertise as a set of rules to draw conclusions from chains of rules applied to initial facts stored in a working memory. As the rules execute, new facts are being generated and added to the working memory causing other rules to execute. Eventually, the rules have completely transformed the facts in memory and no rule can execute. The working memory contains the conclusions that the rules derived. This flexible control, inherent to rule-based systems, differs from predefined control structures found in programs of traditional programming languages. Rules can be easily modified or extended to adjust the performance of the rule-based system. Thus, rule-based systems are an ideal method for dealing with the heterogeneous nature of SOA applications and their evolving artifacts, to identify and extract abstractions automatically and make them available for inspection.

Through experiments and case studies involving domain experts we create a set of rules that identify abstractions within the SOA artifacts, and extract and transform these abstractions into machine-readable representations. In essence, the rules capture an expert's knowledge and skills to identify useful excerpts of information relevant to software maintenance tasks and the reasoning engine automates the process of the expert's analysis of SOA artifacts by executing chains of rules on the artifacts once they are committed to the engine's working memory.

B. System Architecture

Fig. 4 shows the system architecture of the knowledge-enhanced search tool. The tool is composed of an *XML annotator*, a *search indexer*, and a *reasoning engine*. It processes XML Files since many SOA artifacts have XML structure (WSDL, XSD, BPEL and many configuration files). As a first step, the tool annotates every element in the input XML files with a unique identifier so that it can be referenced in the reasoning engine and during searches. After annotation, the files are loaded both into the search indexer and the reasoning engine. This engine runs the DROOLS Expert rule-based system to identify and construct abstractions from the input sources [25].

The engine executes rules on XML elements in the imported files to identify abstractions existing within the artifacts and build them in working memory. As abstractions are committed to the working memory as temporary results the rules may subsequently discover new abstractions and relationships between them. Finally after all rules have fired, working memory is queried to store the abstractions in files that can then be displayed in response to searches in support of maintenance tasks. Each abstraction is formatted as an XML snippet that includes constituents and relations from the SOA artifacts to model the abstraction. The final output is in the form of three XML files, one containing the set of abstractions, another containing cross-references when one abstraction refers to another, and a third describing the search index for the Apache Solr search platform [26].

C. Design of the Knowledge Base

Our case study produced three types of abstractions to support maintenance activities: A) data type summaries, B) services, and C) BPEL invoke relationships. Based on these findings, we analyzed artifacts from the WebAutoParts SOA composite application to look for abstractions and to identify the information that is needed to produce them. From this information, rules and representations were built that match XML elements in the SOA artifacts and transform them into new representations to describe the different abstractions.

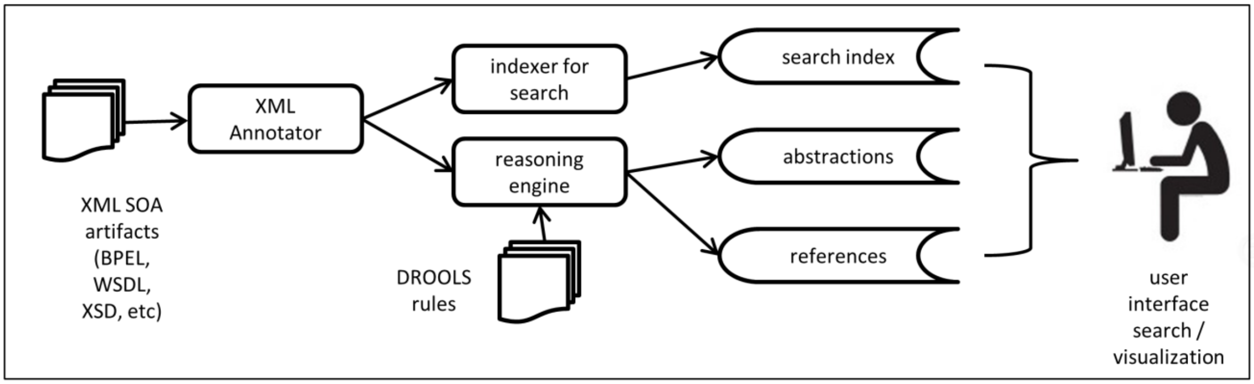

Fig. 4. Architecture For Knowledge-Based Search Tool

In order to make the program extendable, XML elements from the SOA artifacts are loaded into a generic structure called an Entity object that holds each element's type, as well as all of its attributes This structure is then used by the DROOLS rules, which contain the knowledge of how to operate on specific vocabularies of XML, to make transformations leading to the construction of Abstraction objects added by the rules to the working memory. Abstractions are subclasses of Entity to ensure that each Abstraction is also an Entity. Finally, Dependency objects store relationships between two Abstraction objects as established by the DROOLS rules. For example, a Dependency object may describe a relationship that exists between a message in a service abstraction and a data type summery abstraction. Each Entity has a Location, which corresponds to a single input file. Location objects also store statistics about the number of Abstractions identified in imported SOA artifact files. The entire object model is depicted in Fig. 5.

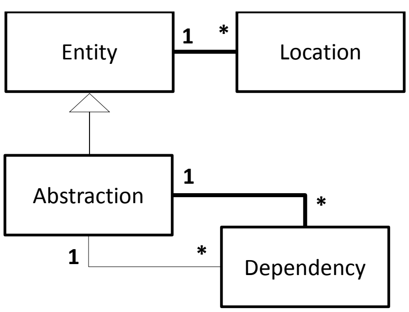

Fig. 5. Object Model For Storing Xml Elements

The rules perform multiple transformations on the XML elements, extracting patterns and tracing the links between complex structures it identifies in the artifacts. The conditional parts of each rule matches against the objects in working memory and its specific values. The action part generates new objects. The rule engine executes the rules until no further transformations can be performed and all abstractions have been identified. Since a generic structure was used for representing XML nodes, additional DROOLS rules may be easily added to the system for new XML vocabularies.

The initial rule set included six rules, three that work together for creating data type summaries, two that create service abstractions, and a single rule that generates high-level BPEL invoke relationships. The three data type summaries rules include a general preprocessing rule, a rule for generating Complex Type Sequences (CTS) and a rule for generating Complex Element Sequences (CES) (details to follow later). The two rules for generating service abstractions perform two independent steps. The first rule looks for services and its operation and the second rule looks for messages associated with operations.

D. Example Application

To show the expressive power of the rule-based approach, consider the problem of identifying which services a BPEL program actually calls. This is not explicit in the code since, to allow for loose coupling of services, BPEL only contains "partner links" which may be resolved to a specific service on deployment or even at runtime.

Table I shows the DROOLS rule and sample fragments of the BPEL and WSDL elements that it operates on. The first part of the table shows the DROOLS rule (lines 1 – 15) and the second part shows the XML fragments from the BPEL and WSDL files (lines 16 – 28). Specifically:

- On line 3, the rule accesses a BPEL partnerLink such as the one on line 16.
- Lines 4 and 5 of the rule match the WSDL's partnerLinkType and role elements from lines 18 and 19 using the "IRepositoryLinkType" and "repository" values.
- On line 6 the rule locates the WSDL binding element of line 22 by matching on the "InventoryRepository PortType".
- Lines 7 and 8 of the rule match the WSDL's service and port elements (lines 23 to 28) using "InventoryRepositoryBinding".
- Finally on lines 10 through 14 the rule creates and stores a new abstraction with the name of the service, thus identifying the actual service called.

As can be seen, a Software Engineer could find it very tedious to follow this chain of relationships by hand, but the rule can abstract the chain to a simple conclusion: OrderProcessing calls InventoryRepository.

TABLE I. CREATION OF AN ABSTRACTION FROM RULES

DROOLS Rule

```
rule "High Level BPEL Partner Link Invokes Abstraction"
when
   $plnk : Abstraction(type == "partnerLink")
   $plnkType : Entity (type == "partnerLinkType" && getAttribute("name") == $plnk.getAttribute("partnerLinkType"))
   $role : Entity (type == "role" && parent == $plnkType && (getAttribute("name").equals($plnk.getAttribute("partnerRole"))))
   $binding : Entity (type == "binding" && getAttribute("type") == $role.getAttribute("portType"))
   $port : Entity (type == "port" && getAttribute("binding") == $binding.getAttribute("name"))
   $service : Entity (type == "service" && hasChild($port))
then
   Abstraction root = new Abstraction($plnkType);
   root.setType("partnerLinkType");
   root.setAbbreviation("PLType");
   root.addAttribute("name", $service.getAttribute("name"));
   $plnk.addChild(root);
end
```

Excerpt from OrderProcessing.BPEL

```
  <bpel:partnerLink name="inventoryRepositoryLink"   partnerLinkType="ns2:IRepositoryLinkType" partnerRole="repository" />
```

Excerpts from InventoryRepositoryArtifacts.WSDL

```
<!-- PARTNER LINK DEFINITION -->
 <plnk:partnerLinkType name="IRepositoryLinkType">
   <plnk:role name="repository" portType="tns:InventoryRepositoryPortType"/>
</plnk:partnerLinkType>
      •••
<!-- BINDING DEFINITION -->
   <binding name="InventoryRepositoryBinding" type="tns:InventoryRepositoryPortType">
      •••
<!-- SERVICE DEFINITION -->
<service name="InventoryRepository">
   <port name="InventoryRepositoryPort" binding="tns:InventoryRepositoryBinding">
      <soap:address location="http://WebAutoParts.com:9990/InventoryRepository" />
   </port>
</service>
```

VI. EVALUATION CASE STUDY AND RESULTS

To illustrate the power and flexibility of the knowledge-based approach to SOA abstraction, we performed an evaluation case study using two different SOA composite applications.

The first case study involved the WebAutoParts example mentioned earlier, and the second involved a Travel Reservation Service originally included as a tutorial example with the NetBeans IDE, version 6.0. Both applications consisted of BPEL orchestration code which invokes services defined by WSDLs and XSDs. Table II shows the dimensions of each application.

In our case studies for SOA search ([23], [24]), Software Engineers had identified several different kinds of abstractions that they thought would be useful. For the evaluation case study of the knowledge-based system, we used the three most prominent of these:

A. *Tree representation of a service*

The description of a service in a WSDL is dispersed and usually needs to be read "bottom up" starting from the port element at the end of the file and proceeding upward through binding, portType, and message elements to arrive at the input and output message structures [1].

TABLE II. SOA APPLICATION COMPOSITION

File Type	WebAutoParts		Travel Reservations	
	Files	Lines	Files	Lines
BPEL	2	189	1	417
WSDL	6	2433	4	524
XSD	2	64	1	17034
Total	10	2686	6	17975

Software Engineers requested a more compact, top-down view of a service, its operations, and its input and output messages.

Fig. 6 gives an example for the USPS shipping-cost service abstraction from the WebAutoParts application.

B. Compact data type summaries

Data handled by a service can be described in many different locations: directly in message structure, in the "types" section of the WSDL, or in imported XSD statements. In turn, each element or type can reference other elements and types, so the Software Engineer trying to understand data must often pull together information from many different parts of several different files. Not surprisingly, participants in our studies requested a more compact summary so that the complete structure could be viewed in one place.

```
SERV - USPS_Service
 OP - GetUSPSRate
  OUT-MSG - GetUSPSRateSoapOut
   ref - GetUSPSRateResponse
  IN-MSG - GetUSPSRateSoapIn
   ref - GetUSPSRate
 OP - GetExtendedUSPSRate
  OUT-MSG - GetExtendedUSPSRateSoapOut
   ref - GetExtendedUSPSRateResponse
  IN-MSG - GetExtendedUSPSRateSoapIn
   ref - GetExtendedUSPSRate
```

Fig. 6. Tree Representation Of The Shipping Cost Service

The two most common patterns for describing structured data in XSD are either as a <complexType> that can be reused in several places or directly in an <element>. Accordingly two kinds of data type summary abstractions were defined in the rule set: Complex Type Sequences (CTS) and Complex Element Sequences (CES). Fig. 7 gives an example of the InventoryQuery CTS used in WebAutoParts. The description of this element in the original XSD takes 12 lines distributed in different parts of the file. The CTS reduces that to the 5 contiguous lines of Fig. 7.

```
CTS - InventoryQueryItemType
 E - element - PartNumber
 E - element - Description
 E - element - UnitPrice
 E - element - NumberInStock
```

Fig. 7. Compact Abstraction Of A Complex Type

C. High-level BPEL invoke relationships

The example in Section II showed some of the complexities of tracing BPEL code. For our rule set we defined an "invoke operation" abstraction that traces from the <invoke> tag in the original BPEL to locate the actual service and operation being called. These "invoke operation" abstractions can be combined to give an approximation of the service call tree of the composite application. Fig. 8 shows an example recovered from WebAutoParts. Note the similarity to the workflow diagram of Fig. 2. For some services, such as USPS_Service, two links are shown because the service offers two different bindings for clients using different versions of SOAP or different transports. Statically, the BPEL cannot reflect which is in use.

```
OrderProcessing invokes:
 USPS_Service.USPS_ServiceSoap12.GetUSPSRate
 USPS_Service.USPS_ServiceSoap.GetUSPSRate
 TaxDataBasic.TaxDataBasicSoap.GetTaxRateUS
 MessageQueue.MessageQueueHttpsPort.SendMessage
 MessageQueue.MessageQueuePort.SendMessage
 AmazonSimpleDB.AmazonSDBPortType.PutAttributes
 InventoryRepository.InventoryRepositoryPort.checkInventory
InventoryRepository invokes:
 AmazonSimpleDB.AmazonSDBPortType.GetAttributes
```

Fig. 8. Services And Operations Called In Webautoparts

D. The evaluation study and its results

The starting point for the evaluation case study was an initial set of rules that had emerged while the knowledge-based system was under development. To guide that development we used our background expertise about Web Services in general, with WebAutoParts being a prominent running example. We wanted to see how hard it would be to adapt this set of rules when we moved to a second, less-familiar system. An independent evaluator who had not participated previously in the project inspected both WebAutoParts and TravelReservations composite applications by manually examining the corresponding BPEL, WSDL, and XSD files. The evaluator identified the services, data types, and invoke relationships which should have been discovered from his perspective. Anything perceived to be unusual or incomplete as assessed by the evaluator was marked as an "anomaly". The results are given in Table III.

Not surprisingly, since WebAutoParts was one of the examples used in developing the initial rule set, only 9 anomalies were encountered, and these fell into 3 categories. One CTS encountered by the evaluator was actually an extension of another data type; the <extension> element in XML schema may be used to add additional data items to a data structure, providing a form of inheritance. The initial rules were not sophisticated enough to identify this case, which only appeared once across both examples.

In another case the evaluator was surprised to see one CES that seemed to appear twice. In fact, two different services happened to use elements having exactly the same name. Perhaps the most interesting case was 6 CESs from one WSDL file which were correctly found, but without their structure. It turned out that this WSDL attached <documentation> tags to the input message of each service operation. These tags confused the rule that assembled the structure of the CES. This particular anomaly illustrates the heterogeneity of SOA implementation styles, with each service developer making different choices about where to place documentation.

More interesting was the Travel Reservations application where we saw even more the effects of heterogeneous implementation styles. The initial rule set correctly identified the large number of data types (CTS and CES) but encountered some significant variations in service and "invoke operation" abstractions.

TABLE III. EVALUATION RESULTS FOR THE INITIAL RULE SET

	Services	**Operations**	**Messages**	**CTS**	**CES**	**Invoke**
WebAutoParts						
- correct	7	44	88	74	135	6
- anomalies				1	8	
Travel Reservations						
- correct	4	12	16	543	172	0
- anomalies	3					6

Travel Reservations includes 4 distinct services, a "top level" BPEL orchestration service and 3 partner services representing airline, hotel, and rental car companies. In this application the services use an asynchronous "request/callback" message exchange pattern, unlike the synchronous "request/response" of WebAutoParts. This means that the top level service provides 3 callback ports in addition to its main entry port. The initial rule set identified these 3 callbacks as additional services, but confusingly it named them the same name as the main entry port so that there appeared to be 3 additional services having the same name.

Another interesting anomaly came in the "invoke operation" abstractions; the initial rule set failed to identify the 6 locations where the top level service called operations on its 3 partners. It turned out that Travel Reservations used extensively the control flow elements of BPEL, leading to a much more complex program structure with more levels of nested XML. This structure defeated the simple initial rule.

Only 7 lines needed modification in the initial rule set to allow the system to handle all the Travel Reservations anomalies. The initial rule base correctly identified most abstractions, with only a few being missed due to anomalies in the way SOA artifacts are constructed. These results are very encouraging; only a few adjustments were need to improve the system's performance in accurately identifying abstractions, which might suggest that with every iteration of applying and refining the rules in the knowledge base, fewer and fewer changes are needed. This illustrates the adaptability of the rule-based approach and its suitability for the heterogeneous and changing nature of SOA applications.

VII. CONCLUSIONS

Ongoing maintenance of SOA composite applications will require scarce and expensive Software Engineering expertise. This expertise will be especially difficult to acquire and sustain because of the heterogeneity of SOA applications and the rapid changes to the environments in which they operate.

One approach to reducing this burden is knowledge-enhanced search: a search tool that integrates higher-level coaching about structures it can analyze with text-based matching for structures that it cannot. However, a search tool must go beyond a simple text matching engine on SOA artifacts because such artifacts require interpretation. An intelligent search tool must provide meaningful results that can assist a software maintainer to discover the relationships between components in the system. We developed a knowledge-based system that automates the task of interpreting SOA artifacts to generate useful abstractions on the collection of services and messages in a SOA composite application. The evaluation case study results indicate that a rule-based approach may provide the much needed adaptability that complex and heterogeneous SOA environment will impose on Software Engineering.

There are a number of enhancements that could be applied to the current tool including 1) a better user interface to provide a smooth integration of text search results and abstraction information and 2) integration of namespace rules to handle namespace information that occur in XML files of SOA artifacts. Ideally both the text search and the abstraction rules should take namespaces into account to improve both search precision and automated reasoning.

Researchers at several of our industry partners have suggested that search could be integrated with ontologies, both domain specific ontologies to clarify the terms used in a specific composite application, and Web Services ontologies to aid the novice in understanding the many element and attribute types that are defined in the standards. Ontologies could provide a deeper meaning to search results that could improve ordering and interpretation of output.

However, perhaps the most important research would be to try knowledge-enhanced search on a wider variety of SOA composite applications with different artifacts. It should be quite possible, for example, to develop rule sets for handling deployment descriptors, enterprise service bus configuration files, database definitions and possibly logged SOAP messages. Such research could help to define the benefits and limitations of knowledge-enhanced search and the application of rule-based systems to extract meaningful information from SOA artifacts.

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Evolutionary Approaches to Expensive Optimisation

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***Abstract*— Surrogate assisted evolutionary algorithms (EA) are rapidly gaining popularity where applications of EA in complex real world problem domains are concerned. Although EAs are powerful global optimizers, finding optimal solution to complex high dimensional, multimodal problems often require very expensive fitness function evaluations. Needless to say, this could brand any population-based iterative optimization technique to be the most crippling choice to handle such problems. Use of approximate model or surrogates provides a much cheaper option. However, naturally this cheaper option comes with its own price! This paper discusses some of the key issues involved with use of approximation in evolutionary algorithm, possible best practices and solutions. Answers to the following questions have been sought: what type of fitness approximation to be used; which approximation model to use; how to integrate the approximation model in EA; how much approximation to use; and how to ensure reliable approximation.**

Keywords—Optimization; Evolutionary Algorithm, Approximation Model; Fitness Approximation; Meta-model; Surrogate

I. INTRODUCTION

Evolutionary algorithms (EAs) have long been accepted as powerful search algorithms, with numerous applications in various science and engineering problem domains. Evolutionary algorithms deserve a special mention as powerful global optimizers. Also, evolutionary algorithms are found to outperform conventional optimization algorithms in problem domains involving, discontinuous, non-differential, multi-modal, noisy, and not well-defined problems. However, many real world optimization problems including engineering design optimization often involve computationally very expensive function evaluations. This makes it impractical for a population-based iterative search technique such as Evolutionary Algorithm (EA) to be used in such problem domains. The runtime for a single function evaluation, in such problems, could be in the range from a fraction of a second to hours of supercomputer time. A viable alternative is to use approximation instead of actual function evaluation to substantially reduce the computation time [39, 50 and 51].

Use of surrogates to speed up optimization is not a new concept [6-15]. The earliest trials date back to the sixties. The most widely used models being Response Surface Methodology [47], Krieging models [55] and artificial neural network models [16]. In the multidisciplinary optimisation (MDO) community, primarily response surface analysis and polynomial fitting techniques are used to build the approximate models [26, 59]. These models work well when single point traditional gradient-based optimisation methods are used. However, they are not well suited for high dimensional multimodal problems as they generally carry out approximation using simple quadratic models. In another approach, multilevel search strategies are developed using special relationship between the approximate and the actual model. An interesting class of such models focuses on having many islands using low accuracy/cheap evaluation models with small number of finite elements that progressively propagate individuals to fewer islands using more accurate but expensive evaluations [60]. As is observed in [32], this approach may suffer from lower complexity, cheap islands having false optima whose fitness values are higher than those in the higher complexity, expensive islands. Rasheed et al. in [50, 51], uses a method of maintaining a large sample of points divided into clusters. Least square quadratic approximations are periodically formed of the entire sample as well as the big clusters. Problem of unevaluable points was taken into account as a design aspect. However, it is only logical to accept that true evaluation should be used along with approximation for reliable results in most practical situations. Another approach using population clustering is that of fitness imitation [32]. Here, the population is clustered into several groups and true evaluation is done only for the cluster representative [39]. The fitness value of other members of the same cluster is estimated by a distance measure. The method may be too simplistic to be reliable, where the population landscape is a complex, multimodal one.

Jin et al. in [36 and 34] analysed the convergence property of approximate fitness-based evolutionary algorithm. It has been observed that incorrect convergence can occur due to false optima introduced by approximate models. Two controlled evolution strategies have been introduced. In this approach, new solutions (offspring) can be (pre)-evaluated by the model. The (pre)-evaluation can be used to indicate promising solutions. It is not clear however, how to decide on the optimal fraction of the new individuals for which true evaluation should be done [17]. In an alternative approach, the optimum is first searched on the model. The obtained optimum is then evaluated on the objective function and added to the training data of the model [52, 58, and 17]. Yet in another approach as proposed in [36], a regularization technique is used to eliminate false minima.

Although using regression and interpolation tools such as least square regression, back propagating artificial neural network, response surface models, and so on are effective means for building the approximate models, accuracy of the result is a major risk involved in using meta-models to replace actual function evaluation [32, 36, 34 and 59]. Fig. 3 depicts how levels of fitness evaluations influence computational expense and accuracy..

Apart from the type of the meta-model generator used, the concepts of using approximate model vary (i) in approximation strategies i.e., what exactly is approximated, (ii) in the model integration mechanism used, and (iii) in model management techniques used [32]. This paper discusses some of these crucial aspects of surrogate assisted evolutionary algorithms.

The rest of the paper is organised as follows. Section II briefly outlines the key issues involved with surrogate assisted evolutionary algorithms; Section III presents the different approximation strategies or types of approximation; Section IV briefly mentions the commonly used approximation model generation tools; while Section V discusses the approximation model integration mechanisms. Section VI and Section VII respectively discusses how much approximation to be used and the issue of quality assurance while using meta-models. Section VIII presents some concluding remarks.

II. Issues Involved With Surrogate Assisted EA

Replacing actual analysis or evaluation by approximate model involves risks and several issues need to be addressed in employing fitness approximations in evolutionary computation (Fig. 1). Of the several issues, foremost are:

- What type of fitness approximation to be used;
- Which approximation model to use;
- How to integrate the approximation model in EA;
- How much approximation to use;
- How to ensure reliable approximation.

Fitness evaluation can be performed by experimental evaluation, complete computational simulation, simplified computational simulation as well as by approximation with surrogates or meta-models; while experimental evaluation can be treated as the true fitness value of a given candidate solution. The tradeoff between computational expense and accuracy is as depicted in Fig. 3. Quite naturally, actual experimental evaluation of fitness gives the highest accuracy but incurs the highest computational cost as well. Fitness evaluation by approximation with surrogates is order of magnitude cheaper compared to the other techniques; but, it also results in lowest accuracy.

Due to inadequate amount of data, ill sampling and the high dimensionality of data sets (input space), it is often very difficult to obtain an *accurate* global approximation of the original fitness function. Hence, the approximate model should be used together with the true fitness function. In most cases, the original fitness function is available, although it is computationally very expensive. Therefore, it is only feasible to use the original fitness function sparingly. The mechanism controlling *how much* of expensive evaluation should be incorporated and in *what way*, is known as *model management* in conventional optimization [21] or *evolution control* in evolutionary computation literature [41, 34]. Also, considering the limited number of sample points that can be available, the quality of the approximate model could be improved by intelligent model selection, use of active data sampling and on-line and off-line weighting, selection of training method and selection of error measures.

Some of these issues related to using approximate model or surrogate in evolutionary algorithm are detailed in the following sections.

III. Types of Approximation

There are various strategies to use approximation in optimization problems. Two such more traditional approaches are [32]: problem approximation and functional approximation. A number of other specialized approaches have been implemented for evolutionary fitness evaluation.

A. Problem Approximation

In this approach, the statement of the problem itself is replaced by a reduced one that is easier to solve. One such example is reported in [5], where, in CFD simulations, the fluid dynamics are described with three-dimensional (3D) Navier-Stokes equations with a turbulence model. Subjected to certain constraints, the 3D flow field can be solved by 2D computations, which is computationally less expensive. Some other examples are reported in [24, 3].

B. Functional Approximation

As the name suggests, in this approach, an alternate and explicit expression is constructed for the objective function, for the purpose of reducing the cost of evaluation.

The surrogate assisted EA techniques reported in [6,8, 10, 12 and 14] uses approximate models to evaluate fitness to reduce the number of actual fitness evaluation. Refer to [32] for more examples on the functional approximation technique.

C. EA Specififc Approximation

This approach is specific for evolutionary algorithms and utilizes the algorithm's structural and functional aspects. *Fitness inheritance* is an example of this technique. In this approach, fitness value of the offspring is estimated from the fitness value of the parents to reduce actual fitness evaluations. In an alternative approach called *fitness imitation*, the individuals are clustered into several groups. Then, only the representative individual of the clusters are evaluated using expensive fitness evaluation. The fitness values of the remaining individuals in the cluster are estimated based on the actual fitness value of the representative individual. Fitness inheritance/ fitness imitation has been used in several researches [66, 56, 18 and 44].

Which of the above three types of approximation should be used in a specific case, naturally depends on the actual intent of using surrogates in the first place.

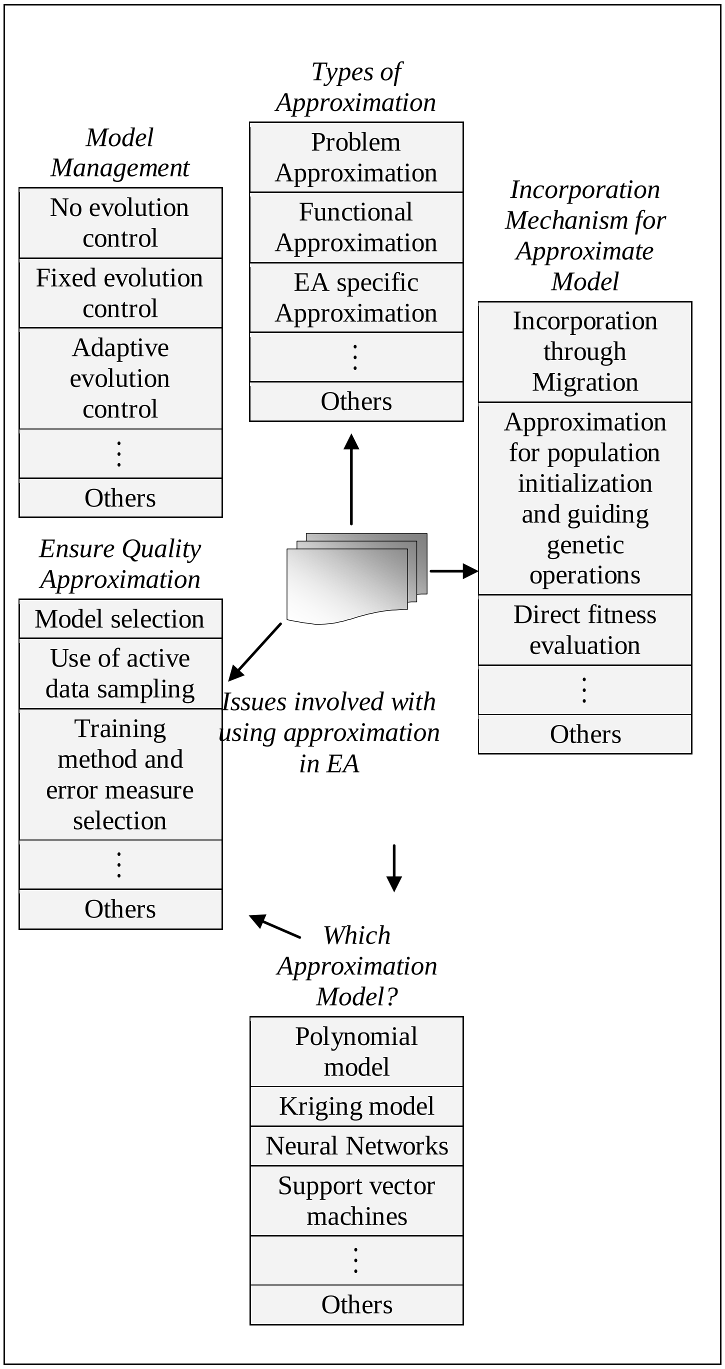

Fig. 1. The issues involved with using approximation in evolutionary algorithm.

IV. APPROXIMATION MODEL GENERATION TOOLS

Approximate models or meta-models in this context are models that are developed to approximate computationally expensive simulation codes. Functional approximation modeling generally involves finding a set of parameters for a given model to find the good, best or perfect fit between a given finite sampling of values of independent variables and associated values of dependent variables [32]. A wide variety of empirical tools are used to generate functional approximation models. Some of the commonly used ones are polynomial interpolation, DACE (design and analysis of computer model) or kriging model, artificial neural networks, regression spline etc. An important characteristic of a meta model generator is generalization. Generalization is the ability to map or predict values that were not considered in the training set while developing the model. The least square method (LSM) performs efficiently only within a small trust region and fails in terms of generalization particularly for complex polynomials with discontinuity in the target function. However, for low dimensional problems with real valued parameters, the polynomial regression models often outperform the connectionist methods. The connectionist models, like the neural networks perform better for high dimensional problems. Unlike the LSM, the kriging models are capable of capturing multiple local extrema, but at the expense of higher computational cost.

It is hard to compare the performances of the different model approximators as performance can be problem dependent and also there are several criteria that need to be considered. However, the most important ones are the accuracy, both on the training and the test data, computational complexity and transparency [32]. One of the serious problems is the introduction of false optima. A desirable tradeoff may be that of lower approximation accuracy if the model is used in global optimization. Some methods for prevention of false minima in neural network are available.

In [32] Jin has suggested the following general rules for model selection. It is recommended to implement first a simple approximate model, for example, a lower order polynomial model to see if the given samples can be fitted with reasonable accuracy. If it fails a model with higher complexity such as higher order polynomials or neural network models should be considered, However, for high dimensional problems with small number of samples, a neural network model is generally preferable. In case of neural network models, in particular a multilayer perceptrons network, the model complexity should be controlled to avoid over-fitting. The gradient descent based method might lead to slow convergence in some cases. The RBF networks show superior performance both in terms of accuracy and training speed for some problems. Support vector machine based approximators, on the other hand, are known to provide robust performance in high dimensional problems with fewer samples.

For further information on non EA specific surrogate assisted design and analysis, see [1, 29].

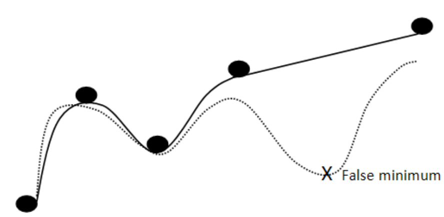

Fig. 2. An example of a false minimum in the approximate model. The solid curve denotes the original function and the dashed curve denotes its approximation.

V. Approximation Model Integration Mechanisms

Integration of approximate model in EA can be done at various levels; e.g., population initialization, with genetic operators such as recombination and mutation, migration in multi-population architecture and so on. The major ones are as discussed below.

- Fitness approximation has been used to initialize population and to guide genetic operators (recombination and mutation) in [4, 50 and 2]. Using approximation only for initialization and for guiding genetic operators is expected to reduce the associated risk of using approximate model as such operations are required only occasionally. However, reduction in actual fitness evaluation may not be that significant [32].
- Yet another approach directly uses approximation based fitness evaluation in order to reduce the number of actual fitness evaluations. This approach of incorporation of approximation is of interest to us in connection with the frameworks proposed in this paper. Different approaches have been proposed with varied degrees of success. Some of the works are reported in [42, 46, 52, 34; 36]. Application to multiobjective optimization has been reported in [23, 48 and 49]. Different approximation model generators and approximation control to some degree have been proposed.
- Approximation with migration may be implemented by maintaining sub-populations at different levels of approximation and allowing migration of individuals from one level of sub-population to another based on pre-defined rules. This has been implemented in [60, 57 and 22].

VI. How Much Approximation?

In the context of reducing the number of actual fitness evaluations, among the various approaches to incorporate approximate models (see Section IV for description of the integration mechanisms), using approximate models for fitness evaluations is most effective. In the real world it is quite common not to have any clear analytical fitness function to accurately compute the fitness of a candidate solution. Depending on the level of estimation used, the compromise between accuracy and computational cost is achieved (see Fig. 3).

Nonetheless, any mechanism to use approximation in EA should try to achieve the following:

- The evolutionary algorithm should converge to the global optimum or at least to a near optimum of the original function. However, in reality it is very difficult to construct such an approximate model due to high dimensionality of the problem, inadequate number of training samples and poor distribution of the candidate solutions in the search space. It is obvious that with some form of approximation control, it is very likely that the evolutionary algorithm will converge to a false optimum introduced by the approximate model. See Fig.2 for an example.
- The overhead of maintaining the approximation model/models should be kept low so that the expenses do not outweigh the benefits.

Using true fitness evaluation along with approximation is thus extremely important to achieve reliable performance by the surrogate assisted EA mechanism. This can be regarded as the issue of model management or evolution control [41, 34].

In the simplest form of model management true function evaluation is not used at all [37, 53]. This is feasible only if the approximate model is considered to be of high fidelity. In most cases, however, evolution control or model management must be used. Some of the popular ones are as follows.

- Surrogates may be used in some of the generations only instead of in all generations of the evolutionary process. Some of the examples are [40, 36 and 20].
- In another approach, surrogates may be used for specific individuals in a generation/ generations only instead of for the entire population. See [27, 36].
- In yet another approach, more than one sub-population may co-evolve using their own surrogate model for fitness evaluation. Migration from one such population to another can occur.
- Specialized model management methods may be necessary for some surrogated assisted evolutionary algorithms [64, 65 and 54]. [65] uses the method for single objective optimization and [54] for multi-objective optimization. Adjusting the frequency of evolution control according to the reliability of the approximate model seems logical [33]. Along with a generation-based approach, [48] has suggested a method to adjust the frequency of evolution control based on the trust region framework [21].
- Relatively recently, Schmidt and Lipson [43] proposed the use of co-evolution technique to address issues such as accuracy of fitness predictor and level of approximation.

Refer to [31] for details on single and multiple surrogate management techniques.

VII. Quality Assurance

Quality assurance is impacted by among other factors, sample selection, approximator selection, and selection of surrogate evaluation metrics. In this section we briefly cover mainly sample and evaluation metric selection issues.

If an approximate model is used for evolutionary computation, both offline and online training will be involved if the evolution is to be controlled. In this context, offline learning denotes the training process before the model is used in evolutionary computation. On the other hand, on-line learning denotes adjusting or rebuilding the model during the evolutionary process. Usually, the samples for offline learning can be generated using Monte-Carlo method; however, it has been shown in different research areas that active selection

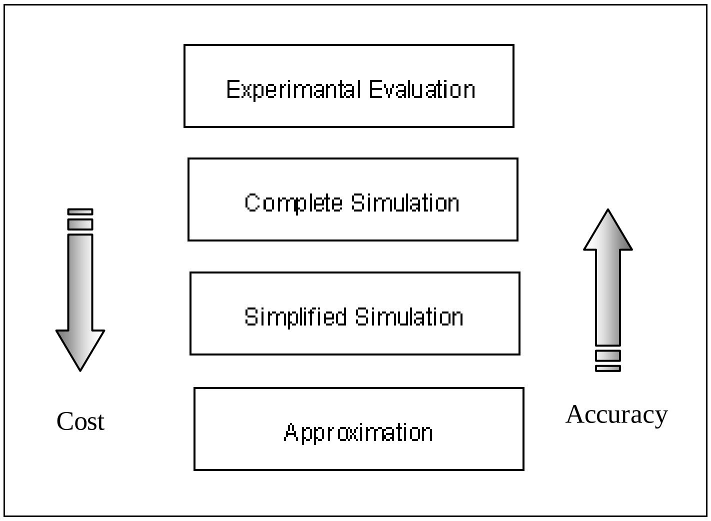

Fig. 3. Levels of fitness evaluations and their respective tradeoffs between computational expense and accuracy.

[45, 38] of the samples will improve the model quality significantly. During on-line learning, data selection is strongly related to the search process [35].

In Section IV we have briefly mentioned about a number of relatively popular approximators and have identified some of their comparative functional aspects. However, it may be noted that selection of approximator is also problem dependent among other factors.

Estimating the model quality by calculating the average approximation error after re-evaluation has been used in some research [62]. [25] has suggested a mechanism for adapting the number of individuals to be evaluated using surrogates. However, there is no clear indication as to which surrogate evaluation metric may be advantageous.

Approximation accuracy is naturally a desirable criterion for effective use of surrogates. One of the main difficulties in achieving approximation accuracy is the high dimensionality of the design space in case of most real world problems. [63] and [65] have used dimension reduction techniques to build the surrogate in a lower dimensional space to overcome this problem.

VIII. Conclusions

Fitness approximation in evolutionary computation is a research area with major potential; but, it has not yet attracted sufficient attention in the evolutionary computation community. In the preceding sections we have presented various issues and aspects of use of approximation in EA. However, several issues still remain to be addressed for approximation based EA to be successful. Below are some of such issues:

- Theoretical research as to how EA can benefit from use of surrogates is lacking. Without a theoretical background it is hard to satisfactorily answer many of the issues raised in this paper.
- Surrogates have been used in local as well global search mechanisms in various researches. However, adequate comparative study is not available to ascertain which one is more beneficial.
- A number of different evolution control or model management techniques are available in the literature, However, still no concrete logic exists that can guide the choice of a particular model management technique over another.
- Research is lacking in the area of surrogate assisted evolutionary algorithm (or other metaheuristics) for combinatorial optimization problems that are computationally intensive.
- Further research is required in the area of surrogate assisted EA for problem domains involving variable input dimensions and dynamic optimization.

Majority of the researches available in the literature uses benchmark test functions to establish the efficacy of the proposed methods involving surrogate assisted evolutionary algorithms. However, it is important to test these methods on real world expensive optimization problems to realize their true potential or lack thereof.

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Identification of Ornamental Plant Functioned as Medicinal Plant Based on Redundant Discrete Wavelet Transformation

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***Abstract*— Human has a duty to preserve the nature. One of the examples is preserving the ornamental plant. Huge economic value of plant trading, escalating esthetical value of one space and medicine efficacy that contained in a plant are some positive values from this plant. However, only few people know about its medicine efficacy. Considering the easiness to obtain and the medicine efficacy, this plant should be an initial treatment of a simple disease or option towards chemical based medicines. In order to let people get acquaint, we need a system that can proper identify this plant. Therefore, we propose to build a system based on Redundant Discrete Wavelet Transformation (RDWT) through its leaf. Since its character is translation invariant that able to produce some robust features to identify ornamental plant. This system was successfully resulting 95.83% of correct classification rate.**

***Keywords*— Identification; ornamental plant; leaf; wavelet; DWT; Redundant DWT; SVM.**

I. Introduction

All living things in this world need oxygen. Plant has an important role to produce oxygen and supply it to them. The cycle between human and the plant is the interesting one. Human respiration resulting carbon dioxide that needed by plant and as a result of photosynthesis plant assembled oxygen that vital for human. According to that cycle, human supposed to preserve the plant to maintain availability of oxygen.

Apart from as the producer of oxygen, some plants also have medicine efficacy. In Japan, medicinal plant has been developing until now, under Research Center for Medicinal Plant Resources. That research center consists of four divisions, start from Hokkaido Division, Tsukuba Division, Wakayama Branch and Tanegashima Division. Each Division has particular features and representative plants. Similar with Japan, Indonesia also has a history about medicinal plants. It starts from Jacobus Rontius in 1592-1631 announced 60 plants which had medicinal function. He wrote to his book titled *De Indiae Untriusquere Naturali et Medica* followed by in 1888 established *Chemis Pharmalogisch Laboratorium* as a part from Bogor Botanical Garden to investigate ingredients from medicinal plants. Currently, many researches about medicinal plants have been conducting under Indonesian Science Board.

Unfortunately, only few people especially young people that acquaint with ornamental plant functioned as a medicinal plant. Elderly people in Indonesia had known its medicine efficacy when the chemical based medicine did not yet attained the popularity. Also, It is easy to find because usually cultivates in front of the house. However, their common purpose of cultivating is to escalating esthetical value only, whereas many simple diseases can be cured using it.

We need an identification system to support people to know more about ornamental plant functioned as a medicinal plant. In this research, we propose to use leaf as identification object of that plant. The main reason is a leaf from ornamental leaf not depends on the season, dissimilar with flower that totally depends on the season.

Leaf identification can be done through identification of leaf shape and arrangement, leaf margin, or leaf venation. This identification is not a current instance in image processing area shown with numbers of researches conducted it. However, most of the works involved features from leaf venation as distinctive value of one leaf with others. One of the work that proposed by Park, Hwang, and Nam [1]. They were developing leaf image retrieval system using four typical venation types from plants collection in Korea. Their work can be separated to be two main steps. First, point selection as representation of leaf venation selected by Curvature Scale Scope Corner Detection. Second, selected points consist of branching point and end point was categorized by calculating density function of feature points.

Other work that related with this research is from Wang et.al [2]. They proposed a system by using automatic marker-controlled watershed segmentation method, as shape features representation they were utilizing 7 Hu geometric moments and 16 Zernike moments. Their work was resulting 92.6% of average correct classification rate.

II. Proposed Method

A. Dataset

The dataset is leaf dataset and obtained by direct acquisition from ornamental plants collection in Indonesia. It consists of 8 classes, and each class has 15 images. Size of the image is 256 x 256 pixels. The classes are Bay (*syzygium polyanthum*), Cananga (*canagium odoratum, lamk*), Mangkokan (*nothopanax scutellarium merr.*), Jasmine (*jasminum sambac [soland]*), Cocor bebek (*kalanchoe* *pinnuta*), Vinca (*catharanthus roseus*), Kestuba (*euphorbia pulcherrima, willd*), Gardenia (*gardenia augusta, merr*).

Identification of leaf can be done through extraction of three features information. First, from the shape and arrangement, second is margin, and last is venation. Scope of this research covered various types of these features that represent the data set. Elliptic, reinform, obtuse, and deltoid types as shape and arrangements feature; dentate, entire, and undulate types as margin feature; pinnate and arcuate types as venation feature.

In order to eliminate unnecessary area outside the leaf, this research proposes segmentation process using Otsu's threshold method. Otsu's threshold calculates threshold to separate foreground and background with minimal intra-class variance. The following is sample images:

Fig. 1. Leaf images in the dataset.

TABLE I. MEDICINE EFFICACY CONTAINED IN ORNAMENTAL PLANT.

Leaf's name	Medicine Efficacy
Bay	Diarrhea, scabies and itching, gastric ulcer.
Cananga	Asthma, bronchitis.
Mangkokan	Mastitis, skin injury, hair loss.
Jasmine	Sore eyes, fever, head ache.
Cocor Bebek	Hemorrhoids, sore joints.
Kestuba	Bruise, irregular menstrual, dysentery.
Gardenia	Diabetes, sprue, constipation.

From Table 1, numbers of ordinary diseases can be cured using the corresponding leaf. Those medicine efficacies can be gained in many serving ways. Most of them are the leaves boil together in the water and apply as a drink. Another way i.e. for skin injuries, only put the mangkokan leaf into the injury area [3].

B. Redundant Discrete Wavelet Transformation (RDWT)

Primary point of RDWT usage is because including in translation invariant family of wavelet transformation. The odd and even pixels are used for approximation and detail coefficients. Distinct with the other RDWT, in this research we decompose the input image with size exactly same, it means there is no frame expansion.

Based on above image, unlike the ordinary DWT the RDWT utilize all pixels in the image. The odd pixel is for scaling coefficient, and the even pixel is for wavelet coefficient. However, these methods still using down sample by 2 when convolves around the image. We use the spline wavelet filter which has one vanishing moment.

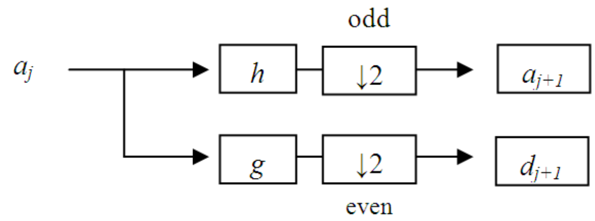

Fig. 2. Forward transformation of RDWT.

The scaling function on the RDWT is very similar with DWT is denoted by $\phi(a_1, a_2) = \phi(a_1)\,\phi(a_2)$. The part from one resolution to next is represented by:

$$c_{j+1}[k,l] = \sum_{m,n} h[m-2k]h[n-2l]c_j[m,n]$$
$$= [\overline{hh} * c_j]_{\downarrow 2,2}[k,l] \qquad (1)$$

The $\downarrow 2{,}2$ is defined as the down sample by factor of 2 along x and y axes. However, as aforementioned this method for scaling coefficient will keep the odd pixel and for wavelet coefficient will keep the even pixel. That is the reason the extension of DWT is called redundant.

The detail coefficient images from three sub wavelets:

Vertical wavelet: $\psi^1(a_1, a_2) = \phi(a_1)\,\psi(a_2)$

Horizontal wavelet: $\psi^2(a_1, a_2) = \psi(a_1)\,\phi(a_2)$

Diagonal Wavelet: $\psi^3(a_1, a_2) = \psi(a_1)\,\psi(a_2)$

In this research, we are also comparing the RDWT method to other methods the CDF 5/3 via lifting and Daubechies DB-4 methods. Lifting method in wavelet transformation supports some advantages. It allows us faster implementation of the wavelet transform, fully in-place calculation, the inverse wavelet transform only by do reverse action toward the decomposition wavelet transform result [4]. CDF 5/3 via lifting based on bi-orthogonal wavelet base function resulting perfect reconstruction image. It utilizes symmetry coefficient between scaling and wavelet function. The main reason of choosing Daubechies orthogonal of length four is needs low-computation time comparing to other wavelets in the Daubechies orthogonal family. We are expecting the competitive results from those methods.

C. Support Vector Machine (SVM)

SVM is a powerful tool for data classification. The indicators are the easiness to apply and impose Structural Risk Minimization (SRM). SRM armed the SVM to have strong ability in generalization of data. Its function is to minimize an upper bound on the expected risk. In principle, SVM learns to obtain optimal boundary with maximum margin that able to separate set of objects with different class of membership.

In order to achieve the maximum margin classifier, we have two options. Hard margin and soft margin are the options that totally depend on linearity of the data. Hard margin SVM is applicable to a linearly separable dataset. However, often the data is not linearly separable. Soft margin SVM emerged as its solution [5]. The optimization problem for the soft margin SVM presented as below:

$$\min_{w,b} \frac{1}{2} \parallel w \parallel^2 + C \sum_{i=1}^{n} \xi_i$$

$$subject\ to: \quad y_i(w^T x_i + b) \geq 1 - \xi_i, \quad \xi_i \geq 0. \quad (2)$$

where $w,\ C,\ \xi,\ b$ are the weight vectors, the penalty of misclassification or margin errors, the margin error, the bias, respectively.

In (2) can lead us to efficient kernel methods approach. A kernel method is an algorithm that depends on the data only through kernel function, which computes a dot product in some possibly high dimensional data.

Using the function ϕ training vector the input space x is mapped into higher dimensional space. $K(x_i, x_j) = \phi(x_i)^T \phi(x_j)$ is called kernel function. The degree of the polynomial kernel can control the flexibility of resulting classifier [6]. It will be appropriate with this research when we classify 8 types of leaf. Polynomial kernel is shown in equation (3).

$$K(x_i, x_j) = (\gamma {x_i}^T x_j + r)^d, \gamma > 0. \quad (3)$$

where γ, r, d are kernel parameters, and i, j denote i^{th}, j^{th} vector in dataset.

In this research, we propose to use Sequential Minimal Optimization (SMO). SMO act as efficient solver of the optimization problem in training of support vector machines. SMO also solves the problems analytically by way of breaks the problems into a series of smallest possible problems.

Despite of this algorithm guaranteed to converge, it used heuristics to choose the pair of multipliers that able to accelerate the rate of converge.

III. EXPERIMENTS

A. Forward Transformation RDWT

The small difference when keep the scaling and wavelet coefficient gave us expected result. The translation invariance feature guarantees the leaf venation is proper extracted from the image.

As decomposition result level 2 of RDWT, CDF 5/3 via lifting method as well as DB-4 are shown with the following images:

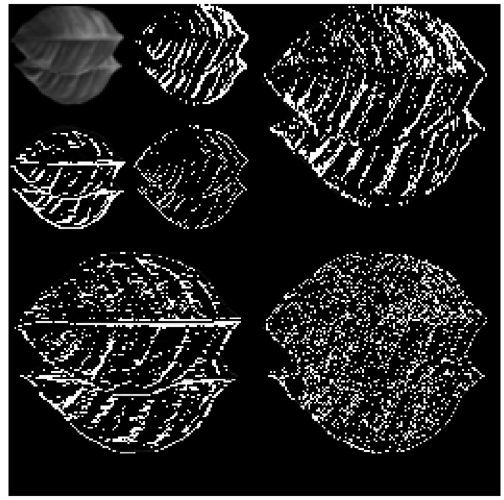

Fig. 3. Forward transformation result for RDWT.

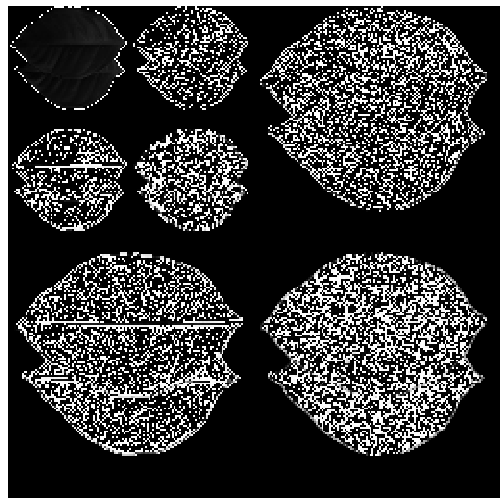

Fig. 4. Forward transformation result for CDF 5/3.

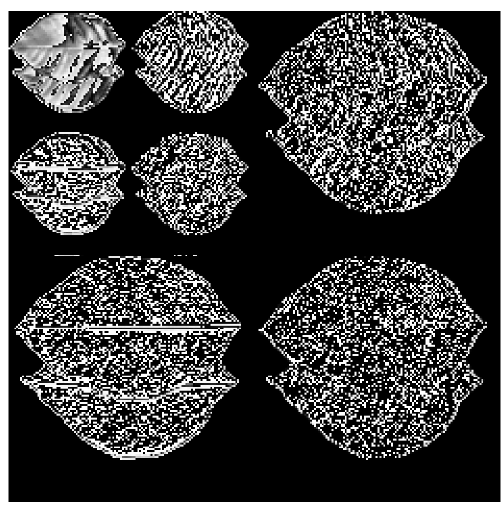

Fig. 5. Forward transformation result for DB-4.

Those images indicate us that decomposition from RDWT is preferable compare to the CDF 5/3 method and DB-4. From the result, it is concluded that the RDWT successfully obtained much clear leaf venation as one crucial point to identify leaf than the CDF.

B. Features Selection

Features selection is based on statistical theory consist of total, mean, variance, and standard deviation. These features capture from decomposition result of each detail, approximation, horizontal, vertical, and diagonal details, visualize as shown in Figure 6.

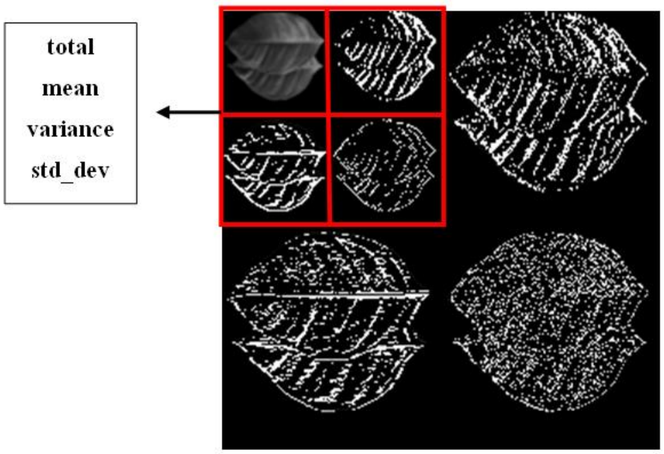

Fig. 6. Features selection.

The mean, variance, and standard deviation are valuable because of their relationships to the normal curve. Variance distribution represents the high frequency data that related with leaf venation. Likewise, total number of wavelet coefficient involved as an additional feature to represent high frequency data. Approximation included because some of distinct factor that contained in the leaf, e.g. leaf shape and arrangement from leaf can be obtained from the approximation coefficient.

C. Classification Results

Data proportion between training and testing data are 80% and 20%, respectively. It means 12 images from each class act as training data and 3 images act as testing data. Table 2, 3, and 4 show the classification performance of three aforementioned methods.

TABLE II. PERFORMANCE RESULT OF LEAF IDENTIFICATION THROUGH WAVELET TRANSFORMATION FOR ALL DETAILS (IN PERCENT)

Method	**L, H, V, D**		
	RDWT	***CDF 5/3***	***DB-4***
Training set	97.92	96.88	97.92
Supplied test set	95.83	87.5	91.67

TABLE III. PERFORMANCE RESULT OF LEAF IDENTIFICATION THROUGH WAVELET TRANSFORMATION FROM THREE HIGH FREQUENCY DETAILS (IN PERCENT)

Method	**H, V, D**		
	RDWT	***CDF 5/3***	***DB-4***
Training set	92.71	83.33	78.13
Supplied test set	79.17	66.67	66.67

TABLE IV. PERFORMANCE RESULT OF LEAF IDENTIFICATION THROUGH WAVELET TRANSFORMATION FROM HORIZONTAL AND VERTICAL DETAILS (IN PERCENT)

Method	**H, V**		
	RDWT	***CDF 5/3***	***DB-4***
Training set	82.29	73.96	72.92
Supplied test set	70.83	58.33	58.33

L, H, V, D denotes approximation detail, horizontal detail, vertical detail and diagonal detail, respectively. We decided to present only {L,H,V,D}, {H,V,D}, and {H,V} as representation of previously mentioned leaf features. High frequency details as well as low frequency detail are needed for the identification, when D detail consists high frequency data only. Performance over the training set shows us how well the SOM learned the data.

Linear classifiers often have simple training algorithms that fit with the number of samples. However, better accuracy is provided by non-linear classifier in many applications. Identification through classification by SMO in table 1 yielded the positive results indicated by all the performances are around 90%. The distribution from 8 classes data attained well separated decision boundary by the non-linear SVM kernel method, in this case is through polynomial kernel function.

The CDF 5/3 and DB-4 in table 2 showed deficient performances with 58.33% of correct classification results. Similar performances showed in table 3 these methods had same values, which was 66.67%. We concluded that the CDF 5/3 and DB-4 had identical characteristics while extracting the feature which are clearly visible as shown in Figure 5 and 6.

From Table 2 and 3, the approximation detail provided significant improvement. It is obvious seen in the supplied test set from the {L,H,V,D} and {H,V,D}, we gained 9.52%, 13.52%, and 15.79% of improvement from RDWT, CDF5/3, and DB-4, respectively. It implied that ornamental leaf feature also occurred in here. In the sequel, at the supplied test result also obtained the result of RDWT is better than CDF 5,3 and DB-4. Utilization of all pixels in RDWT's behavior can extract clearly of leaf venation as well as texture feature, when the other methods only extract texture feature from leaf.

Misclassification for each method often happened in class A and B. The reason was class A and B had same characteristics from the shape and arrangement as well as leaf venation.

Even though, we were involving human perception, often made a mistake while trying to classify those classes. It will be the future study to select another appropriate wavelet transformation's feature representation from the leaf.

IV. CONCLUSION

This research has successfully conducted RDWT to extract relevant leaf information. This modified version of DWT in utilization of odd and even pixels was resulting preferable result in comparison with CDF 5/3 via lifting and Daubechies DB-4 methods. In general, feature selection in this proposed method also in the proper way has represented the leaf information through its leaf venation and shape. Though we were working on different dataset, obtained correct classification result of 95.83% is greater than Wang et.al work. Even we gained the proper classification performance. On the other hand, we are still facing another serious problem. Another problem is how we can educate and motivate people after they get acquainted to use this ornamental leaf as an alternative of treatment from one disease. Since the self-dosage thing will not be a cure, but aggravate the disease even worse.

V. FUTURE WORK

The future work that can be interesting from this current progress is conducting the other wavelet transformation method with better support of contour extraction. One of the promising candidates is dyadic wavelet transformation via lifting method. Frame expansion and shift invariant features are the guarantee points to obtain better contour extraction. The other future study is an extension from this basic feature extraction in relation with complexity of the dataset.

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Robot Path Planning using An Ant Colony Optimization Approach: A Survey

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***Abstract*— Path planning problem, is a challenging topic in robotics. Indeed, a significant amount of research has been devoted to this problem in recent years. The ant colony optimization algorithm is another approach to solve this problem. Each ant drops a quantity of artificial pheromone on every point that the ant passes through. This pheromone simply changes the probability that the next ant becomes attracted to a particular grid point. The techniques described in the paper adapt a global attraction term which guides ants to head toward the destination point. The paper describes the various techniques for the robot path planning using the Ant colony Algorithm. The paper also provides the brief comparison of the three techniques described in the paper.**

Keywords*— Path planning; Ant colony algorithm; collision avoidance.

I. INTRODUCTION

Path-planning can be described as the task of navigating a mobile robot around a space in which a number of obstacles that have to be avoided. Optimal paths could be paths that minimize the amount of turning, the amount of braking or whatever a specific application requires. Path-planning requires a *map* of the environment and the robot to be aware of its *location* with respect to the map. A reliable navigation algorithm must be able to

- Identify the current location of the robot,
- Avoid any collisions,
- Determine a path to the object.

Mobile robot navigation problem is a challenging problem, and a number of studies have been attempted, resulting in a significant number of solutions. Three major concerns regarding robot navigation problems are efficiency, safety and accuracy. The main scope of the path finding problem involves the efficiency and safety issues. The path finding problem can be overcome by combining global path planning and local path planning.[4]. The robot path planning methods could be classified into different kinds based on different situations. Depending on the environment where the robot is located, the path planning methods can be classified into the following two types as shown in Figure 1.

- Robot path planning in a static environment which contain only the static obstacles in the map; and
- Robot path planning in a dynamic environment which has static and dynamic obstacles in the map.

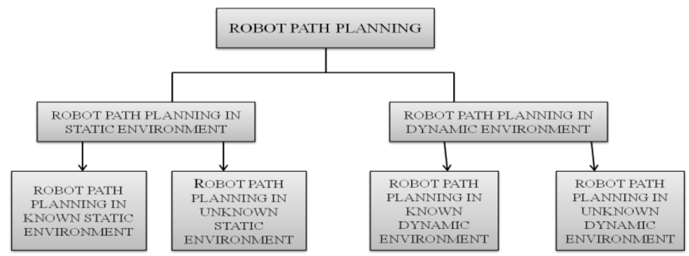

Fig. 1. Classification of the robot path planning methods.

Each of these two types could be further divided into two sub-groups depending on how much the robot knows about the entire information of the surrounding environment:

- Robot path planning in a clearly known environment in which the robot already knows the location of the obstacles before it starts to move.
- Robot path planning in a partly known or uncertain environment in which the robot probes the environment using sensors to acquire the local information of the location, shape and size of obstacles and then uses the information to proceed local path planning.

II. REVIEW OF LITERATURE

Yogita Gigras, Kusum Gupta [1] proposed algorithm for collision avoidance using backtracking and used the ant colony algorithm for finding the optimum shortest path to reach to the destination. Buniyamin N., Sariff N., Wan Ngah W.A.J., Mohamad Z.[2] worked together to solve the Robot Path Planning(RPP) problem. They proposed the accurate representation of heuristic and visibility equations of state transition rules. The proposed algorithm was applied within a global static map having feasible free space nodes. Michael Brand, Michael Masuda, Nicole Wehner, Xiao-Hua Yu [3] investigated the application of ACO to robot path planning in a dynamic environment. They compared two different pheromone re-initialization schemes and describe the best of them based on the simulation result. O. Hachour[4] proposed algorithm for path planning of autonomous mobile robot in an unknown environment. The robot travels within the environment sensing and avoiding obstacles that come across its way to the target station. Daniel Angus [5] modified the existing Ant System meta heuristic by including three parameters: cost, visibility and pheromone. Based on this a new algorithm for the Shortest Path Ant Colony Optimization

(SPACO) was developed. The most important parameter included in this algorithm to solve shortest path problem is visibility. M.Dorigo, C. Blum [6] in Ant Colony Optimization theory: A Survey discussed the theoretical results of Ant Colony Optimization algorithms. They analyzed convergence results, connection between ACO algorithm and random gradient ascent within the model based search. Shahram Saeedi and Iraj Mahdavi[7] formulated a mathematical model to obtain the shortest path using Ant Colony Optimization. The model required calculation of shortest path between sources to target minimizing cost in the absence of any obstacle. Vinay Rishiwal et al. [8] proposed application of Ant Colony Optimization algorithm to find optimal paths in terrain maps. The algorithm uses penalty maps of the terrain maps as an input. The Terrain features such as land, forest etc are identified with different colors. Transition probability maintains a balance between pheromone intensity and heuristic information. Yee Zi Cong et al. [9] solved the mobile robot path planning problem using ACO algorithm. Each map consisted of static obstacles in different orientations. Each map was represented in a grid form with equal number of rows and columns. Song-Hiang Chia et al. [10] used Any Colony Optimization algorithm to solve the mobile robot path planning problem in such a way that the artificial ant reaches the target point from source point avoiding obstacles. The problem was modeled in a grid platform.

III. PATH PLANNING TECHNIQUES

Path planning can be achieved through various different methods. In this section we describe the various techniques for path planning.

A. Particle swarm optimization (PSO):-

Particle swarm optimization (PSO) method is relatively a new population-based intelligence algorithm and exhibits good performance in optimization problems. In the optimization process, the particles become more and more similar, and gather into the neighborhood of the best particle in the swarm, which makes the swarm prematurely converged possibly around the local solution. PSO do not guarantee an optimal solution is ever found. More specifically, PSO does not use the gradient of the problem being optimized.

B. Genetic algorithm (GA) :-

Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.

In a genetic algorithm, a population of strings called chromosomes or the genotype of the genome, which encodes candidate solutions called individuals, creatures, or phenotypes to an optimization problem, evolves toward better solutions. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached.

C. Tabu Search:-

Fred Glover proposed in 1986 a new approach, which he called tabu search, to allow hill climbing to overcome local optima. The basic principle of tabu search is to pursue the search whenever a local optimum is encountered by allowing non-improving moves; cycling back to previously visited solutions is prevented by the use of memories, called tabu lists, which record the recent history of the search. Tabu search (TS) is based on the premise that problem solving, in order to qualify as intelligent, must incorporate adaptive memory and responsive exploration.

D. Simulated Annealing (SA)

Simulated annealing (SA) is a random-search technique which exploits an analogy between the way in which a metal cools and freezes into a minimum energy crystalline structure and the search for a minimum in a more general system. Simulated annealing was developed in 1983 to deal with highly nonlinear problems. SA approaches the global maximization problem similarly to using a bouncing ball that can bounce over mountains from valley to valley.

E. Reactive Search Optimization (RSO)

Reactive Search Optimization (RSO) advocates the integration of machine learning techniques into search heuristics for solving complex optimization problems.. Reactive Search Optimization also addresses a scientific issue related to the reproducibility of results and to the objective evaluation of methods. *Reactive Search* is a methodology for solving hard optimization problems, both in the discrete and continuous domain, based on the integration of machine learning and optimization in an online manner.

F. Ant Colony Algorithms

The Ant Colony Optimization Algorithm is a relatively recent approach to solving optimization problems by simulating the behavior of real ant colonies. The Ant Colony System (ACS) models the behavior of ants, which are known to be able to find the shortest path from their nest to a food source.. Ants accomplish this by depositing a substance called a pheromone as they move. This chemical trail can be detected by other ants, which are probabilistically more likely to follow a path rich in pheromone. This trail information can be utilized to adapt to sudden unexpected changes to the terrain, such as when an obstruction blocks a previously used part of the path (Figure 2).

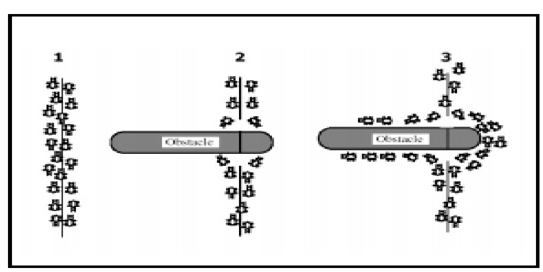

Fig. 2. Obstacles between Ants nest and Food

The shortest path around such an obstacle will be probabilistically chosen just as frequently as a longer path - however the pheromone trail will be more quickly reconstituted along the shorter path, as there are more ants moving this way per time unit (Figure 3).

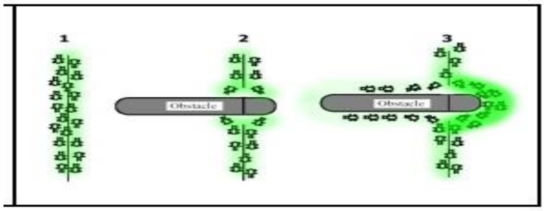

Fig. 3. Pheromone build-up allows ants to reestablish the shortest path.

Since the ants are more inclined to choose a path with higher pheromone levels, the ants rapidly converge on the stronger pheromone trail, and thus divert more and more ants along the shorter path. This particular behavior of ant colonies has inspired the Ant Colony Optimization algorithm, in which a set of artificial ants co-operate to find solutions to a given optimization problem by depositing pheromone trails throughout the search space. Existing implementations of the algorithm deal exclusively with discrete search spaces, and have been demonstrated to reliably and efficiently solve a variety of combinatorial optimization problems. Table 1 gives brief overview, of the three most successful algoritms: ant system (Dorigo 1992, Dorigo et al. 1991, 1996), ant colony system (ACS) (Dorigo & Gambardella 1997), and MAX-MIN ant system (MMAS) (Stützle & Hoos 2000). The historical order in which they were introduced

TABLE I. OVERVIEW OF THE THREE SUCCESSFUL ANT COLONY ALGORITHM

Algorithm	Tour Construct	Evaporation	Pheromone	Updation
AS (Ant System) Dorigo et al. 1991,	random proportional rule	all arcs lowered with constant factor	$\tau_{ij} \leftarrow (1-\rho)\cdot\tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}$	deposit on all arcs visited by all ants
ACS (Ant Colony System) Dorigo and Gambardella (1997).	Pseudo random proportional rule	only arcs of the best-so-far tour are lowered	$\tau_{ij} = (1-\varphi).\tau_{ij} + \varphi.\tau_0$ where $\varphi \in (0,1)$ is the pheromone decay coefficient	deposit only on arcs of the best so-far tour
MMAS (MAX-MIN Ant System) Stützle and Hoos (2000)	random proportional rule	all arcs lowered with constant factor	$\tau_{ij} \leftarrow (1-\rho).\tau_{ij} +.\Delta\tau_{bestij}$ where $\Delta\tau_{bestij} = 1/L_{best}$	deposit only either by the iteration best-ant, or the best-sofar ant; interval [_min; _max]

IV. ALGORITHMS FOR ROBOT PATH PLANNING

A. Path planning Algorithm[1]

The algorithm described below tries to avoid the collision and also suggest the steps to be followed during the occurrence of the obstacles.[1].

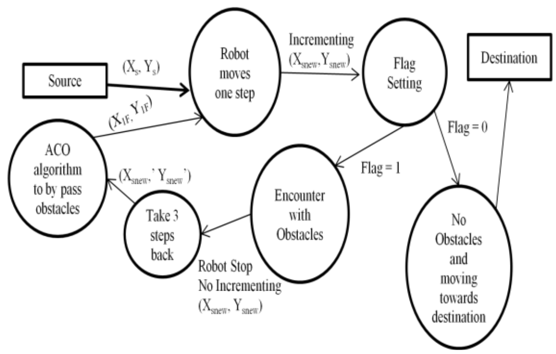

Fig. 4. Layout of robot path planning [1]

1) Source

Robot start walking from a fixed source point (X_s,Y_s) .

2) Robot Moves one step

The value of (X_s,Y_s) is changed to (X_{snew},Y_{snew}) when the robot moves one step ahead by using the below equation:-

$$X_{snew} = X_{prev} + step * \cos(\theta) \qquad (1)$$

$$Y_{snew} = Y_{prev} + step * \sin(\theta) \qquad (2)$$

Where X_{prev},Y_{prev} denotes where the robot is currently situated. Robot's next position is determined by adding the product of step size and the cos(ɵ) and sin(ɵ).Where ɵ is dynamic angle and it can be calculated by:-

$$\theta = \tan^{-1} X_{prev}/Y_{prev} \qquad (3)$$

3) Flag Setting

Robot see the value of the flag, if its value is zero it means there is no obstacle and robot can take a one step ahead to the destination point.

4) Encounter with obstacle

Whenever the robot encounter with obstacle, it has to stop moving. In our proposed work, twenty obstacle are generated randomly which is of rectangular shape. Number of obstacles is fixed which a constraint in our work is.

5) Take three step back

Whenever the robot encounter with obstacle, robot stop moving and take three step back by using the following equation:-

$$X_{snew} = X_{prev} - 3 * step * \cos(\theta) \quad (4)$$

$$Y_{snew} = Y_{prev} - 3 * step * \sin(\theta) \quad (5)$$

$$\theta = \tan^{-1} X_{prev}/Y_{prev} \qquad (6)$$

6) Destination

Finally robot has to reach at the point (X_T,Y_T), which is fixed. Robot has to bypass the obstacle and by following optimal path has to reach to target point.

7) Apply the ACO algorithm to bypass the obstacle

ACO is used to find out the optimal one i.e. locally or globally optimal. This algorithm is implemented in two steps.

a) In first step, the edge is selected on the basis of probability formula. Assume that ant k is located at node i, uses the pheromone deposited on the edge (i,j) to compute the probability of choosing next node$_{ij}$

$$P_{ij} = \begin{cases} \frac{\tau_{ij}\alpha}{\sum_{j \in N_{i(k)}} \tau_{ij}\alpha} & if\ j\ \varepsilon\ N_{i(k)} \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

Where α denotes the degree of importance of pheromone trail and $Ni^{(k)}$ indicates the set of neighbor of ant k when located at node i except the last node visited by ant k, which helps to prevent the ant k for returning to the same node.

b) In second step, once all the ants complete their tour, then global optimization of the pheromone trail takes place.

$$\tau_{ij} = (1-\rho).\rho + \sum_{k=1}^{N} \Delta\tau_{ij}^{(k)} \quad (8)$$

Where ρ Є (0,1) is the evaporation rate and $\Delta\tau_{ij}^{(k)}$ and Δ is the amount of pheromone deposited on the edge (i,j) selected by the best ant k. The aim of pheromone updating is to increase the pheromone value associated with optimal path. The pheromone deposited on arc (i, j) by the best ant k is $\Delta\tau_{ij}^{(k)}$. Where,

$$\Delta\tau_{ij^{(k)}} = \frac{Q}{L_k} \quad (9)$$

Here Q is a constant and L_k is the length of the path traversed by the best ant k. This equation is also implemented as:-

$$\Delta\tau_{ij}^{(k)} = \begin{cases} \frac{T_{best}}{f_{worst}} & if\ (i,j)\varepsilon\ global\ best\ tour \\ 0 & otherwise \end{cases} \quad (10)$$

B. Robot Path Planning Algorithm By Buniyamin N Et,Al[2]

For the Robot Path Planning (RPP) purpose, the proposed path planning algorithm is a modification of the original ACO concept (also known as Ant Colony System) proposed by Marco Dorigo [2]. Figure 5 outlines the implementation of ACO for RPP of a mobile robot. The model and concept of the proposed algorithm is as follows:

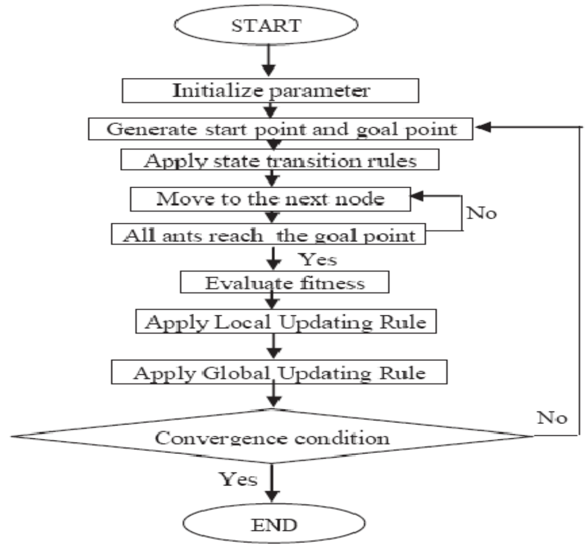

Fig. 5. Outline for the implementation of ACO for RPP of a mobile robot [2]

Starting from the start node located at x-y coordinate of (1,1), the Robot will start to move from one node to other feasible adjacent nodes.

8) The robot will then take the next step to move randomly based on the probability given by equation (11) :

Probabilityij (t) = Heuristic$_{ij}$ (t)*Pheromone$_{ij}$(t)
=[(1/distance between vector start point to next point and start point to reference line to goal)β * (trail/ Σtrail)σ] (11)

Where Heuristic (t) indicates every possible adjacent nodes to be traversed by the robot in its grid position at every t time. The quantity of Pheromone$_{ij}$ (t) is an accumulated pheromone between the nodes when the robot traverses at every t time. Therefore, the probability equation depends on both values where it will guide the robot to choose every possible node in every t time. Each time robot construct a path from one node to another, the pheromone amount will be reduced locally by the given evaporation rate using the formula of update local rules as shown below:

$$T_{ij(new\ trail)} \leftarrow (1-\rho) * T_{ij(old\ trail)} \quad (12)$$

where ρ=evaporation rate

This equation shows that each time the robot move from one node to another node, the amount of local pheromone will be updated in parallel.

This process is important to prevent the map from getting unlimited accumulation of pheromone and enables the algorithm to forget a bad decision that has been previously made.

Once the robot found its path to goal, the fitness of robot will be calculated. This covers the calculation of distance or path cost each robot takes to traverse from start point to goal point by using derivation of objective function for RPP below:

$$Distance = \sqrt[2]{(y_2 - y_1)^2 + (x_2 - x_1)^2} \qquad (13)$$

The fitness value will then be used for the process of global update. When all robots reach the destination, the robots will update the value of pheromone globally based on the fitness found by each robot by using Equation (14) below.

This process will be repeated as the path being traverse by robots in each generation is determined using this global value. During the process, the path with the shorter distance will be chosen as the probability to be chosen is higher compared to the path with the longer distance. The equation of global updating is derived in (14) and (15) below:

$$t_{ij} \leftarrow t_{ij} + \sum \Delta t_{ij}^{k} \qquad (14)$$

Where $\Delta\ t_{ij}^{k}$ is the amount of pheromone of robot m deposits on the path it has visited. It's defined as below:

$$\Delta\tau_{ij(k)} = \frac{Q}{L_k} \qquad (15)$$

Where Q is number of nodes and L_k is the length of the path P_k built by the robots.

The process will be repeated from Step 1 to Step 5 until the process converges. The process will stop when all robots traverse the same path that shows the shortest path to goal has been found.

C. Robot Dynamic Path planning by Michael Brand, et.al[3]

In this section, the proposed ant colony optimization algorithm is applied for robot path planning in a grid network. Since our goal is to find the shortest path between the starting and ending positions, the total path length is chosen to be the cost or reward associated with each possible solution. The simulation starts with a "clean" environment; i.e., there is no obstacle in the original network. The upper-left comer is chosen to be the starting point and the lower-right comer is chosen to be the destination. All the pheromones are initialized as 0. The ant colony algorithm is then applied to find the shortest path and pheromones are deposited. A computational flow chart is shown in Figure6.

Consider a network where ants can travel between different nodes. Using pheromone deposits, the probability that an ant k located in node i will choose to go to another node in the network is given by the equation (16)

$$p_{ij}^{k} = \left|\begin{cases} \dfrac{\left(\tau_{ij}^{k}\right)^{\alpha} . \left(\eta_{ij}^{k}\right)^{\beta}}{\sum_{l \in N_i^k} \left(\tau_{il}^{k}\right)^{\alpha} . \left(\eta_{il}^{k}\right)^{\beta}} & if\ j \in N_i^k \\ 0 & if\ j \notin N_i^k \end{cases}\right| \qquad (16)$$

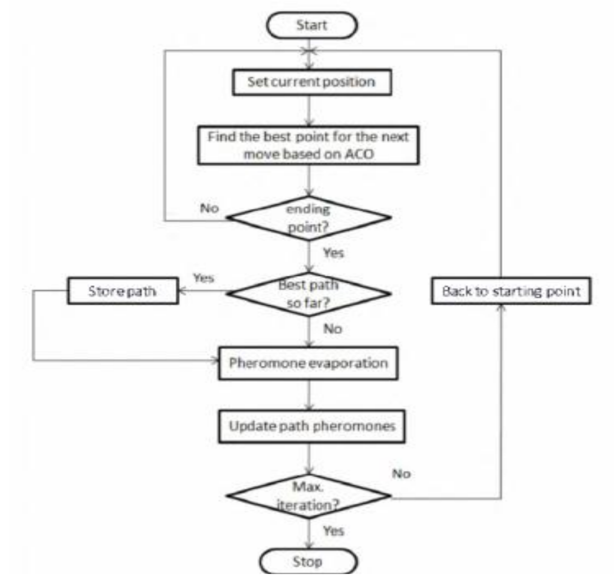

Fig. 6. Computational flow chart of ACO[3].

Where pheromone levels are denoted by τ^{k}_{ij} .The summation in the denominator considers possible choices (or neighboring nodes) in the set N_i^k when the ant is at node i. α, β and η_{ij}^{k} are usually application dependent; where η_{ij}^{k} represents the heuristic information, and the values of α and β weigh the importance of the pheromone and heuristic values. When β = 0, $(\eta_{ij}^{k)\ \beta}$ then the probability only depends on the pheromone levels; on the other hand, when α = 0, the probability only depends on heuristic values that is, the node that is the closest one to the current node has the highest probability of being selected.

The pheromone levels of the path (from node i to i), can evaporate with a percentage ρ (also called the evaporation rate):

$$\tau_{ij} \leftarrow (1 - \rho) . \tau_{ij} \qquad (17)$$

Where 0<ρ< 1. After pheromone evaporation occurs, the new pheromone levels are updated with the additional pheromone laid by the ants that just crossed the path:

$$\tau_{ij} \leftarrow \tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \qquad (18)$$

Where Ck is the associated cost or reward of ant k for choosing this path.

$$\Delta\tau_{ij}^{k} = \frac{1}{C^k} \qquad (19)$$

IV. Comparison Between Algorithms

The brief overview of the different proposed algorithm and the facts that allow them to differ from each other are described in this section. In this Table 2. section compares the proposed algorithm based on the variations done by each algorithm in the basic ant colony algorithm which helps to overcome the drawback of the basic ant colony algorithm and provide us with the better solution for robot path optimization.

TABLE II. COMPARISON BETWEEN ALGORITHMS

Properties	Path planning Algorithm[1]	Robot Path Planning Algorithm by Buniyamin N et,al[2]	Robot Dynamic Path planning by Michael Brand, et.al[3]
Objective Of Algorithm	Collision Avoidence	To find an optiml path based on distance time and number of itertions	To find the Shortest Path
Use of Flag	Yes. use the flag value to indicate the presence of the obstacles.	No.	No.
Action on obstacle occurrence	Allow the robot to move three steps back if the obstacles are detected	The path containing an obstacle is considered as unfeasible in the initial stage only.	Reinitialization of the pheromone in the network is done.
Average Time Taken	27.911018 sec.	63 seconds	100 seconds

V. APPLICATIONS OF ANT COLONY ALGORITHM

In recent years, the interest of the scientific community in ACO has risen sharply. The use of an algorithms providing exponential time worst complexity is often infeasible in practice, thus ACO algorithms can be useful for quickly finding high quality solutions. This section describes the applications of the Ant colony algorithm in various fields.

A. Applications To NP-Hard Problems

ACO has been tested on probably more than one hundred different NP-hard problems. The problems include the sequential ordering problem, openshop scheduling problems, some variants of vehicle routing problems, classification problems, and protein–ligand docking. Many of the tackled problems can be considered as falling into one of the following categories:

- *routing problems:-* as they arise, for example, in the distribution of goods;
- *assignment problems*, where a set of items has to be assigned to a given number of resources subject to some constraints.
- *scheduling problems*, which–in the widest sense–are concerned with the allocation of scarce resources to tasks over time; and
- *subset problems*, where a solution to a problem is considered to be a selection of a subset of available items.

B. Applications To Telecommunication Networks

ACO algorithms have shown to be a very effective approach for routing problems in telecommunication networks where the properties of the system, such as the cost of using links or the availability of nodes, varies over time. ACO algorithms were first applied to routing problems in circuit switched networks. A well-known example is AntNet[11].

C. Applications To Industrial Problems

The first to exploit algorithms based on the ACO metaheuristic is EuroBios (www.eurobios.com). They have applied ACO to a number of different scheduling problems such as a continuous two-stage flow shop problem with finite reservoirs.

Another company that has played, and still plays, a very important role in promoting the real-world application of ACO is AntOptima. AntOptima's researchers have developed a set of tools for the solution of vehicle routing problems whose optimization algorithms are based on ACO.

VI. CURRENT RESEARCH TOPICS IN ACO

A significant part of research on ACO is still concerned with applications. However, increasing attention is and will be given to even more challenging problems that, for example, involve *multiple objectives*, *dynamic modifications* of the data, and the *stochastic nature* of the objective function and of the constraints.

A. Dynamic optimization problems

Dynamic problems are characterized by the fact that the search space changes during time. Hence, while searching, the conditions of the search, the definition of the problem instance and, thus, the quality of the solutions already found may change. For this problem, ACO algorithms belong to the state-of-the-art techniques [11][12].

An ACS algorithm has also been applied to dynamic vehicle routing problems, showing good behavior on randomly generated as well as real-world instances.

B. Stochastic optimization problems

In stochastic optimization problems, some variables have a stochastic nature. The probabilistic traveling salesman problem (PTSP) was the first stochastic problem tackled by ACO algorithms. The first ACO algorithm for this problem was proposed by Bianchi et al.[13] Further ACO algorithms for the PTSP have been proposed by Branke and Guntsch[14] , Gutjahr[15][16], and Birattari et al[17].

C. Multi-objective optimization

Multiple objectives can often be handled by ordering or weighting them according to their relative importance. In the two-colony ACS algorithm for the vehicle routing problem with time window constraints[18] and in the MMAS for the bi-objective two-machine permutation flow shop problem , the multi-objective optimization problem is handled by ordering the objectives; differently,

D. Continuous optimization

ACO algorithms have been applied to continuous optimization. When an algorithm designed for combinatorial optimization is used to tackle a continuous problem, the simplest approach would be to divide the domain of each variable into a set of intervals [21][22]. Research in this direction is currently ongoing.

VII. Conclusion

In this paper, ACO is used to find the shortest navigational path of mobile robot avoiding obstacles to reach the target station from the source station. In this paper, the results of detailed investigation of ACO algorithms being applied to a path optimization problem have been presented Overcoming the limitations of the algorithms represent a challenge for future research. No matter how many obstacles are present, this algorithm does not devote an excessive amount of time in iteration process. ACO approach takes some unnecessary steps, so that the algorithm does not return the best solution. Furthermore, a global attraction term had to be added to lead ant to reach the goal point. Eliminating this term may cause not only the ant wander around in the map, but also the ant may become stuck at a point which will prevent the ant .i.e. robot from reaching to the goal. This paper also gives the comparison about the different algorithm described in the paper. Based on the comparison we can state that the Path Planning Algorithm by Yogita Gigras et.al. is better than the other two based on the average time taken.

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Vibration Control of MR Damper Landing Gear

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***ABSTRACT*— In the field of Automation, Fuzzy Control Fuzzy control has significant merits which are utilized in intelligent controllers, especially for vibration control systems. This paper is concerned with the application aspects of the developed MR damper for landing gear system, to attenuate the sustained vibrations during the landing phase. Also a comparative study is made on the responses obtained from the MR damper landing gear by utilizing PID and Fuzzy PID controllers.Theory is a well-known technique to acquire the desired response of different non-linear systems.**

Keywords*—Magneto-Rheological (MR) damper; Proportional Integral Derivative (PID) Controller; Fuzzy Logic Controller (FLC)

I. INTRODUCTION

Magneto-Rheological (MR) Fluid is an intelligent material with an ability to amend itself from free-flowing viscous liquids to semi-solid state under the effect of magnetic field. By the use of such materials, MR's damping force can be utilized to obtain proper control on vibration, which is not possible with traditional dampers based on oil gas or hydraulic pressure. The specific properties of MR damper make the same to be used in this application such as small volume, light in weight, low energy dissipation, quick response and a large adjustable range of damping force [2].

During the process of takeoff and landing of an aircraft, the impact of road is greatly reduced by the landing gear that consists of the MR damper [3]. The fundamental characteristics of MR damper is its non linearity, hysteresis and saturation while that of landing gear is a multifaceted nonlinear pulsation system with multiple degrees of freedom. Thus it is difficult to create an accurate mathematical model, i.e. why the traditional linear control model can't achieve the satisfactory outcome.

By and large, a variety of nonlinear control algorithms are utilized for nonlinear systems such as optimal control, fuzzy control and neural network control in order to improve the response of the respective system. Among all the algorithms, the fuzzy control has various merits; simple modeling, high control precision and better capability [1]. Therefore, Fuzzy Controller is applied in intelligent controllers, especially for vibration control systems. Juang and Cheng have developed four ANN controllers to land a simulated aircraft under the effect of vibration and tested by FNC varying turbulence conditions [6].

II. MR DAMPER

A magneto-rheological (MR) fluid is a non-colloidal solution, composed of ferromagnetic particles dispersed in a non-conductive carrier fluid. On the application of external magnetic field, the rheological property of the MR fluids reversely changes. Due to this feature, a large number of devices such as shock absorbers, vibration insulators, brakes and clutches use MR fluids in their respective operations. Apart from this, devices using the MR fluid can be made uncomplicated in construction, high in power, and low in inertia. Therefore, the use of the MR fluid actuators is very effectual in improving the function and performance of conventional control systems [2].

Recently, the authors have projected an electromagnetic design methodology for the magneto-rheological (MR) damper. If sufficient amount of magnetic field is applied to the MR fluid, the performance of the MR damper is improved to a much larger extent [3]. For this purpose, two effective approaches are proposed: In the first approach, the redundant bulk of the repression is removed due to which the magnetic flux path is abridged, hence improving the static characteristics of the MR damper; While in the second approach, the cross-sectional vicinity of the ferromagnetic material, through which the magnetic flux passes is minimized, due to which the magnetic reluctance of the material increases hence improving the dynamic and hysteresis characteristics [3]. The superiority of the proposed design methodology to a conventional one was verified through the magnetic field analysis and a series of basic experiments.

III. MATHEMATICAL MODELING OF MR DAMPER LANDING GEAR

Vibration Control System for landing gears mainly consists of MR damper and tires. MR damper plays the major role in vibration control. Its mechanical model is shown in Fig.1 [11] and based upon its model, the equations respective to the model can be postulated as in Eq.1 and Eq.2.

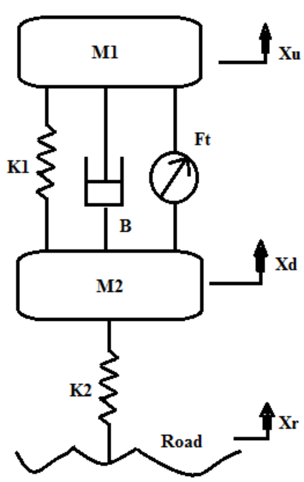

Fig. 1. Mechanical Model of Landing Gear with MR Damper

$X = [X_1, X_2, X_3, X_4]^T$ Eq.1

Where,

$X_1 = X_u - X_d$; $X_2 = \dot{X}_u$;

$X_3 = X_d - X_r$; $X_4 = \dot{X}_d$;

The output variables can be seen as:

$Y = [Y_1, Y_2, Y_3, Y_4]$ Eq.2

$Y_1 = X_1$; $Y_2 = \dot{X}_2$;

$Y_3 = K2X_3$; $Y_4 = X_4$;

Here the output parameters are:

Y_1 = dynamic deflection of landing gear

Y_2 = acceleration of fuselage

Y_3 = tire dynamic load

Y_4 = vertical velocity of the tire.

The state equation of the mechanical model can be obtained as in Eq.3 [11].

$$\mathbf{X = A\,x + B\,u}$$
$$\mathbf{Y = C\,x + D\,u} \qquad \text{Eq.3}$$

Where,

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 0 & -1 \\ \frac{-K1}{M1} & \frac{-B}{M1} & 0 & \frac{B}{M1} \\ 0 & 0 & 0 & 1 \\ \frac{K1}{M2} & \frac{B}{M2} & \frac{-K2}{M2} & \frac{B}{M2} \end{bmatrix}; \mathbf{B} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{1}{M1} \\ -1 & 0 \\ 0 & \frac{-1}{M2} \end{bmatrix}$$

$$\mathbf{C} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ \frac{-K1}{M1} & \frac{-B}{M1} & 0 & \frac{B}{M1} \\ 0 & 0 & K & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \mathbf{D} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{1}{M1} \\ 0 & 0 \\ 0 & 0 \end{bmatrix};$$

IV. DESIGN OF FUZZY PID CONTROLLER

Fuzzy Logic Controller (FLCs) is used for simulating the linearized landing configuration of an aircraft. FLCs rule base are implemented as a function of the inputs i.e. the error '*e*' and the rate of change of error 'e_c'. The FLC outputs i.e. the Proportional 'K_P', Integral 'K_I' and the Derivative 'K_D' coefficients are determined by the Centroid method.

A. *Fuzzification of the Inputs and Outputs*

The actual variation of Vibration Error '*e*' and its rate 'e_c' lies in the range of [*e*,*e*] and [-e_c, e_c]. The domains of vibration error *e* and its change rate e_c on fuzzy sets by the quantity factors K_e and K_{ec} is defined by Eq.4:

e, ec = {-10,-9,-8…,0,1, 2…,8,9,10} Eq.4

Inputs and outputs linguistic variables can be defined on fuzzy subsets as:

e, e_c , u = (NB, NM, NS, Z, PS, PM, PB)

where, the linguistic description of subset are: *NB*=negative large, *NM*=negative medium, *NS*=negative small, *Z*=zero, *PS*=positive small, *PM*=positive medium, *PB*=positive large.

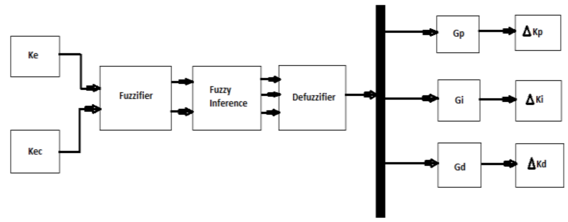

Fig. 1. Fuzzy Controller Block Diagram

The design principle of fuzzy controller is shown in Fig.1. The membership functions of the input i.e. the error and the rate of change of error of the vibration and the output i.e. the appropriate values of Proportional (K_P), Integral (K_I) and Derivative (K_D) coefficients are defined as in triangular form, can be viewed in Fig.2-3 and Fig.4-6 respectively.

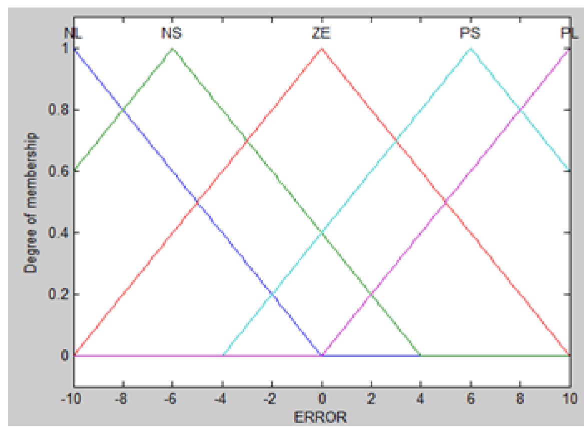

Fig. 2. MF of Error as an input to FLC

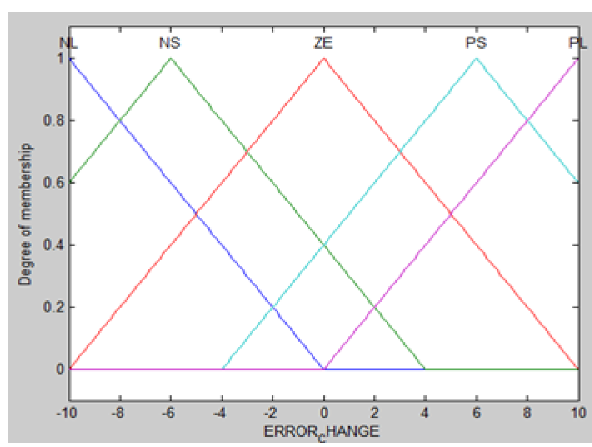

Fig. 3. MF of rate of change of error as an input to FLC

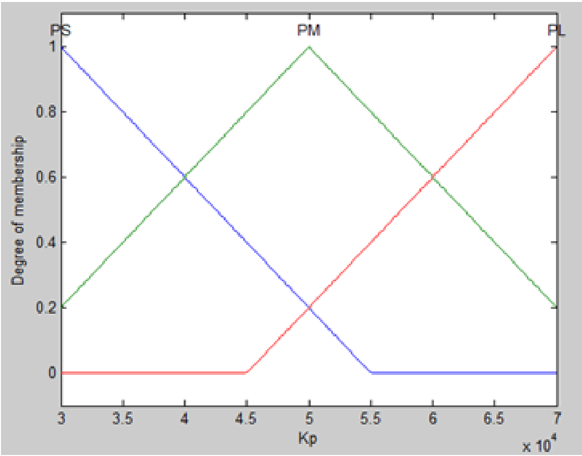

Fig. 4. MF of K_P as an output from FLC

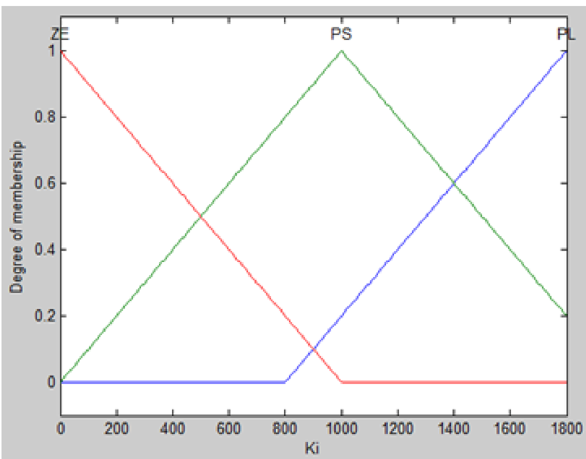

Fig. 5. MF of K_i as an output from FLC

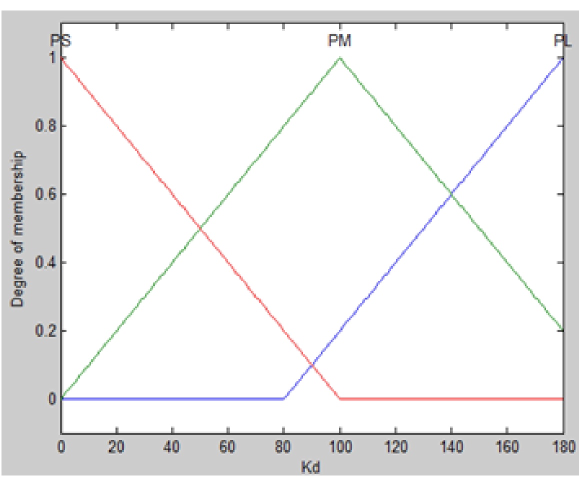

Fig. 6. MF of K_d as an output from FLC

B. *Fuzzy Inference*

Fuzzy inference is used to put together fuzzy rules. The influence of the parameters K_e and K_{ec} on the output characteristics of landing gear with MR damper can be summarized as follows:

1) In order to speed up the response of the MR damper, larger values of |e| are essential, which prefer larger proportional coefficient i.e. Kp and smaller derivative coefficient i.e. Kd. In order to avoid the large overshoot of landing gear due to integral saturation, the integral coefficient i.e. Ki = 0.

2) The value of |e| is taken middle large to control the response time and smaller overshoot of the MR damper; for which middle values of proportional, integral and derivative coefficients are adopted.

3) The smaller values of |e| are used to ensure a good steady-state performance; for which the larger values of proportional and integral coefficients are necessary. If rate of change of error is small then derivative coefficient is large and vice-versa. Usually, middle values are taken for the derivative coefficient to ensure the anti- interference performance of the whole system.

Depending upon the vibration error '*e*' and the change rate of error 'e_c' of MR damper landing gear, triangular membership functions are used to build fuzzy rules of the order as shown in Table.1.

TABLE I. RULES FOR THE LANDING GEAR SYSTEM

		Rate of Change of Error				
		NL	**NS**	**Z**	**PS**	**PL**
Error	**NL**	PL/ZE/PS	PL/PS/PS	PL/PS/PS	PL/PS/PS	PL/ZE/PS
	NS	PM/PS/PM	PM/PS/PS	PM/PS/PM	PM/PS/PM	PM/PS/PM
	Z	PL/PL/PS	PL/PL/PM	PL/PL/PL	PL/PL/PM	PL/PL/PS
	PS	PM/PS/PM	PM/PS/PM	PM/PS/PM	PM/PS/PM	PM/PS/PM
	PL	PL/ZE/PS	PL/PS/PS	PL/PS/PS	PL/PS/PS	PL/ZE/PS

The pictorial overview of the rule bases can be depicted as in Fig.7. These rules can also be written in the form of **IF – THEN** statements and the simulink model is given in Fig.8.

The parameters of landing gear with MR damper are taken into account, which are selected in simulation as shown in Eq.5:

$$M1 = 250000kg;\ M2 = 800kg;$$
$$B = 50000Ns/m;\ K1 = 6 \times 10^5\ N/m;$$
$$K2 = 3.2 \times 10^6\ N/m; \qquad \text{Eq.5}$$

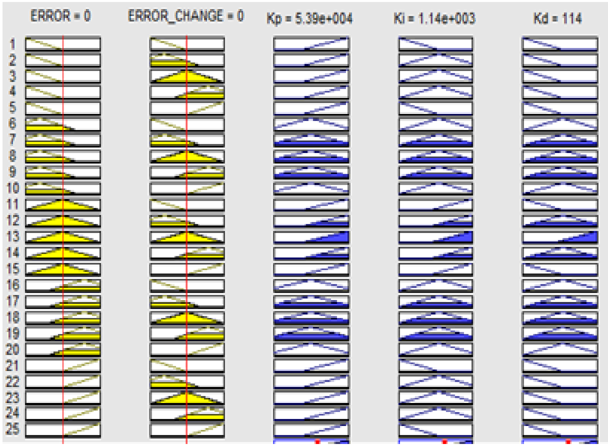

Fig. 7. Rule Viewer

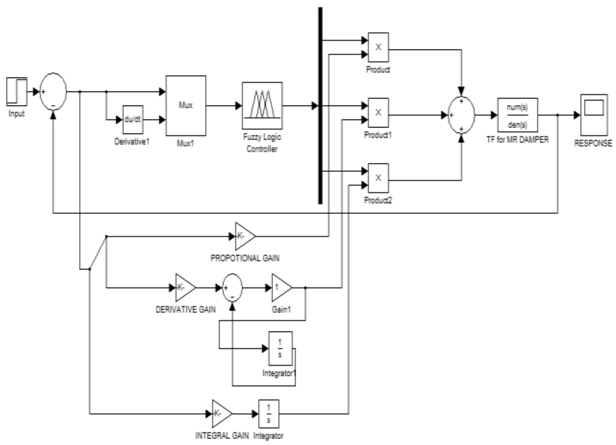

Fig. 8. Simulink Block Diagram

Fuzzy toolbox of Simulink is utilized to build the different control models of MR damper and their comparison, including PID and Fuzzy PID control model. The simulation results indicate the smooth response of the system during the process of take-off and landing. Under the arbitrary road surface input, different properties of MR damper can be examined.

V. Graphs Obtained

The Surface Viewer has a special capability to study two (or more) inputs and one output at very same time. The Fuzzy Logic Controller outputs i.e. K_P, K_I and K_D can also be studied using surface viewer as shown in Fig.9-11.

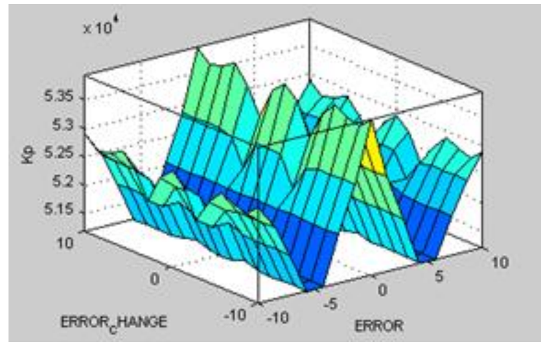

Fig. 9. Surface View for K_P

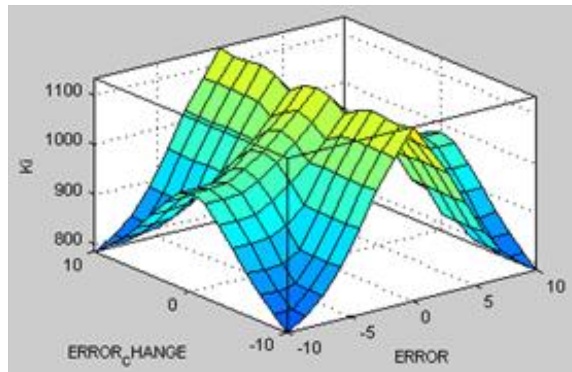

Fig. 10. Surface View for K_i

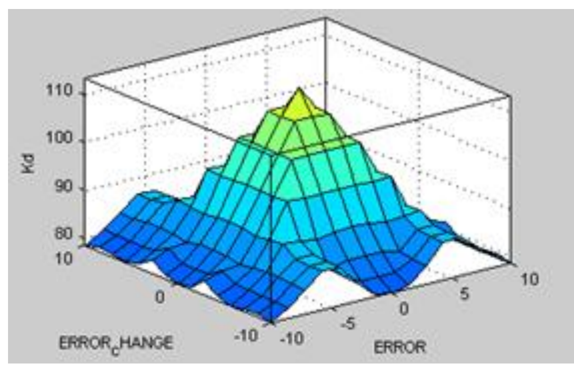

Fig. 11. Surface View for K_d

VI. Results And Conclusion

By comparison and analysis, the simulation results show that Fuzzy PID control action is superior as compared to that of PID controller, that can effectively reduce the vibration of the fuselage and improve the smooth landing response of the aircraft. The simulation analysis of the system noticeably indicates the usage of MR damper in aircraft landing gear. Fuzzy PID control approach has a vital influence on the optimization control for MR damper. The output response of the MR damper based Landing gear system using PID controller and Fuzzy PID controller can be shown as in Fig.12 and Fig.13 respectively.

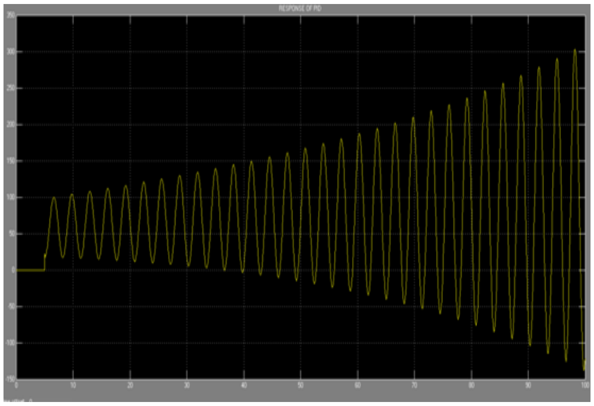

Fig. 12. Waveform for PID Controller

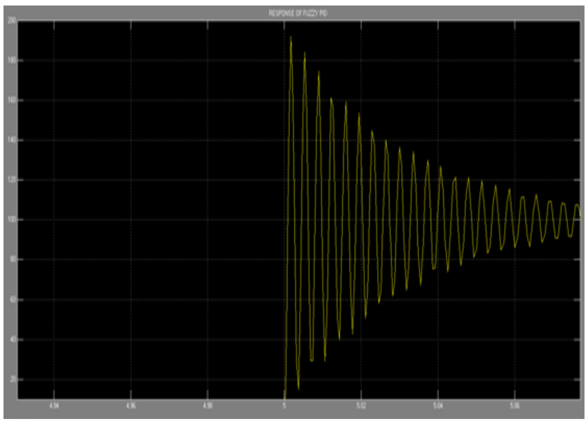

Fig. 13. Waveform for Fuzzy PID Controller

Here, we observe that due to the non-linearity of the MR Damper, the response of the PID controller is unstable whilst, when we make use of a Fuzzy PID controller, a steady output is achieved. The oscillations that are continuous and increasing in amplitude using PID controller are being replaced by damped oscillations tending to a finite value, resulting in the attenuation of the undesired vibrations in the landing phase.

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Decision Making and Emergency Communication System in Rescue Simulation for People with Disabilities

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***Abstract*—Decision making and emergency communication system play an important role in rescue process when emergency situations happen. The rescue process will be more effective if we have appropriate decision making method and accessible emergency communication system. In this paper, we propose a centralized rescue model for people with disabilities. The decision making method to decide which volunteers should help which disabled persons is proposed by utilizing the auction mechanism. The GIS data are used to present the objects in a large-scale disaster simulation environment such as roads, buildings, and humans. The Gama simulation platform is used to test our proposed rescue simulation model.**

Keywords— Rescue Simulation for people with disablities; GIS Multi Agent-based Rescue Simulation; Auction based Decision Making

I. Introduction

People with disabilities have been addressed as vulnerable population in emergency situations. Japantimes reported "The death rate among disabled people living in coastal areas of Miyagi Prefecture when the March 2011 earthquake and tsunami struck was 2.5 times higher than the overall average". The helps for these kind of population are very important for disaster mitigation. The studies on how to help disabled people in emergency situations effectively are getting urgent.

In an emergency situation, a human tends to perform two main activities: the rescue and the evacuation. It is very difficult and costly if we want to do experiments on human rescue and or evacuation behaviors physically in real scale level. It is found that multi agent-based simulation makes it possible to simulate the human activities in rescue and evacuation process [1, 2]. A multi agent-based model is composed of individual units, situated in an explicit space, and provided with their own attributes and rules [3]. This model is particularly suitable for modeling human behaviors, as human characteristics can be presented as agent behaviors. Therefore, the multi agent-based model is widely used for rescue and evacuation simulation [1-5].

Recently, Geographic Information Systems (GIS) is also integrated with a multi agent-based model for emergency simulation. GIS map can be used to solve complex planning and decision making problems. In this study, GIS map is used to model objects such as road, building, human, fire with various properties to describe the objects condition. With the help of GIS data, it enables the disaster space to be closer to a real situation [5-10].

Rescue activities are taken by volunteers to help disabled persons. The decision of choosing the order in which victims should be helped to give first-aid and transportation with the least delay to the shelter is very important. The decision making is based on several criteria such as the health condition of the victims, the location of the victims, and the location of the volunteers.

The rest of the paper is organized as follows. Section 2 reviews related works. Section 3 describes the centralized rescue model and the rescue decision making method. Section 4 provides the experimental results of different evacuation scenarios. Finally, section 5 summarizes the work of this paper.

II. Related Works

In general, there are three types of simulation model (1) flow based, (2) cellular automata, (3) agent based, which are used for emergency simulation. Kisko et al. (1998) employs a flow based model to simulate the physical environment as a network of nodes. The physical structures, such as rooms, stairs, lobbies, and hallways are represented as nodes which are connected to comprise a evacuation space. This approach allows viewing the movement of evacuees as a continuous flow, not as an aggregate of persons varying in physical abilities, individual dispositions and direction of movement [11]. Gregor et al. (2008) presents a large scale microscopic evacuation simulation. Each evacuee is modeled as an individual agent that optimizes its personal evacuation route. The objective is a Nash equilibrium, where every agent attempts to find a route that is optimal for the agent [12]. Fahy (1996; 1999) proposes an agent based model for evacuation simulation. This model allows taking in account the social interaction and emergent group response. The travel time is a function of density and speed within a constructed network of nodes and arcs [13, 14]. Gobelbecker et al. (2009) presents a method to acquire GIS data to design a large scale disaster simulation environment. The GIS data is retrieved from a public source through the website OpenStreetMap.org. The data is then converted to the Robocup Rescue Simulation system format, enabling a simulation on a real world scenario [15]. Sato et al. (2011) also proposed a method to create realistic maps using the open GIS data. The experiment shows the differences between two types of maps: the map generated from the program and the map created from the real data [2]. Ren et al. (2009) presents an agent-based modeling and simulation using Repast software to construct crowd evacuation for emergency response for an area under a fire. Characteristics of the people are modeled and tested by iterative simulation. The simulation results demonstrate the effect of various parameters of agents [3]. Cole (2005) studied on GIS agent-based technology for emergency simulation. This research discusses about the simulation of crowding, panic and disaster management [6]. Quang et al. (2009) proposes the approach of multi-agent-based simulation based on participatory design and interactive learning with experts' preferences for rescue simulation [9]. Hunsberger et al. (2000), Beatriz et al. (2003) and Chan et al. (2005) apply the auction mechanism to solve the task allocation problem in rescue decision making. Christensen et al. (2008) presents the BUMMPEE model, an agent-based simulation capable of simulating a heterogeneous population according to variation in individual criteria. This method allows simulating the behaviors of people with disabilities in emergency situation [23].

Our study will focus mainly on proposing a rescue model for people with disabilities in large scale environment. This rescue model provides some specific functions to help disabled people effectively when emergency situation occurs.

III. PROPOSED RESCUE MODEL AND DECISION MAKING METHOD

A. *Proposed Rescue Model*

Important components of an evacuation plan are the ability to receive critical information about an emergency, how to respond to an emergency, and where to go to receive assistance. We proposes a wearable device which is attached to body of disabled people. This device measures the condition of the disabled persons such as their heart rate, body temperature and attitude; the device can also be used to trace the location of the disabled persons by GPS. Those information will be sent to emergency center automatically. The emergency center will then collect those information together with information from volunteers to assign which volunteer should help which disabled persons.

The centralized rescue model presented has three types of agents: volunteers, disabled people and route network. The route network is also considered as an agent because the condition of traffic in a certain route can be changed when a disaster occurs. The general rescue model is shown in Figure 1.

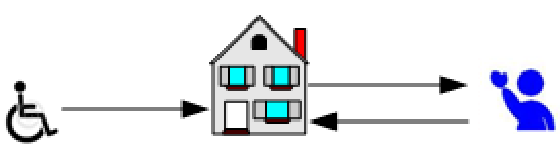


Fig. 1. Centralized Rescue Model

Before starting the simulation, every agent has to be connected to the emergency center in order to send and receive information. The types of data exchanged between agents and emergency center are listed as below.

Message from agent

A1: To request for connection to the emergency center
A2: To acknowledge the connection
A3: Inform the movement to another position
A4: Inform the rescue action for victim
A5: Inform the load action for victim
A6: Inform the unload action for victim
A7: Inform the inactive status

Message from emergency center

K1: To confirm the success of the connection
K2: To confirm the failure of the connection
K3: To send decisive information

Before starting the simulation, every agent will send the command A1 to request for connection to the emergency center. The emergency center will return the response with a command K1 or K2 corresponding to the success or failure of their connection respectively. If the connection is established, the agent will send the command A2 to acknowledge the connection. The initial process of simulation is shown in Figure 2.

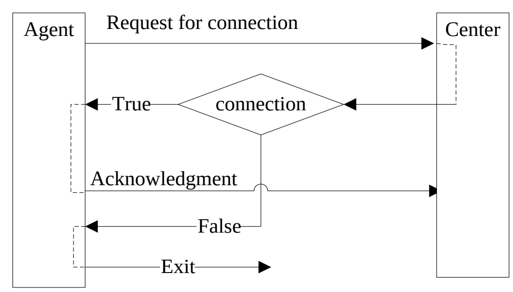


Fig. 2. Initial Process

After the initial process, all the connected agents will receive the decisive information such as the location of agents and health level via command K3; after that the rescue agents will make a decision of action and submit to the center using one of the commands from A3 to A7. At every cycle in the simulation, each rescue agent receives a command K3 as its own decisive information from the center, and then submits back an action command. The status of disaster space is sent to the viewer for visualization of simulation. The repeating steps of simulation are shown in figure 3.

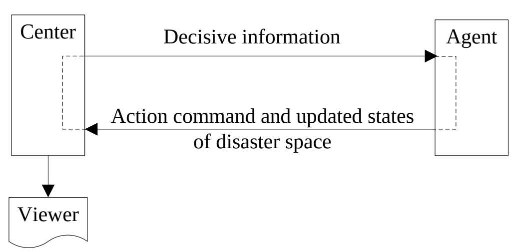


Fig. 3. Simulation Cycles

B. *Disaster Area Model*

The disaster area is modeled as a collection of objects: Nodes, Buildings, Roads, and Humans. Each object has properties such as its positions, shape and is identified by a unique ID. Table 1 to Table 7 presents the properties of Nodes, Buildings, Roads and Humans object respectively. These properties are derived from RoboCup rescue platform with some modifications.

TABLE I. PROPERTIES OF NODE OBJECT

Property	Unit	Description
x,y		The x-y coordinate
Edges	ID	The connected roads and buildings

TABLE II. PROPERTIES OF BUILDING OBJECT

Property	Description
x, y	The x-y coordinate of the representative point
Entrances	Node connecting buildings and roads

TABLE III. PROPERTIES OF ROAD OBJECT

Property	Unit	Description
StartPoint and EndPoint	[ID]	Point to enter the road. It must be the node or a building
Length and Width	[mm]	Length and width of the road
Lane	[Line]	Number of traffic lanes
BlockedLane	[Line]	Number of blocked traffic lanes
ClearCost	[Cycle]	The cost required for clearing the block

TABLE IV. PROPERTIES OF VICTIM AGENT

Property	Unit	Description
Position	ID	An object that the victim is on.
PositionInRoad	[mm]	A length from the StartPoint of road when the victim is on a road, otherwise it is zero
HealthLevel	[health point]	Health level of victim. The victim dies when this becomes zero
DamagePoint	[health point]	Health level dwindles by DamagePoint in every cycle. DamagePoint becomes zero immediately after the victim arrives at a shelter.
DisabilityType	Type[1..7]	Type of disability which is listed in table VII
DisabilityLevel	[low/high]	Victim who has high Disability level, will have higher DamagePoint

TABLE V. PROPERTIES OF VOLUNTEER AGENT

Property	Unit	Description
Position	ID	An object that the volunteer is on.
PositionInRoad	[mm]	A length from the StartPoint of road when the humanoid is on a road, otherwise it is zero
CurrentAction	Type[1..3]	One of action listed in table VII
Energy	Level[1..5]	Amount of gasoline in vehicle
PanicLevel	Level[0..9]	Shows the hesitance level of decision

TABLE VI. ACTION OF VOLUNTEER AGENT

ActionID	Action	Description
1	Stationary	Volunteer stays still
2	MoveToVictim	Volunteer go to location of victims
3	MoveToShelter	Volunteer carry victim to shelter

TABLE VII. TYPE OF DISABILITY

Type	Description
1	Cognitive Impairment
2	Dexterity Impairment (Arms/Hands/Fingers)
3	Mobility Impairment
4	Elderly
5	Hearing Impairment
6	Speech and Language Impairment
7	Visual Impairment

The topographical relations of objects are illustrated from Figure 4 to Figure 7. The representative point is assigned to every object, and the distance between two objects is calculated from their representative points.

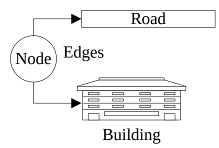


Fig. 4. Node object

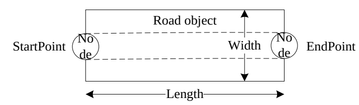


Fig. 5. Road object

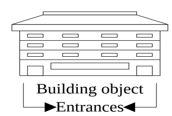


Fig. 6. Building object

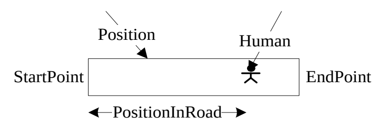


Fig. 7. Human object

C. Decision Making Method

The decision making of volunteers to help disabled persons can be treated as a task allocation problem (Nair et al. 2002; Boffo et al. 2007; Hunsberger et al. 2000; Beatriz et al. 2003; Chan et al. 2005). The central agents carry out the task allocation for the rescue scenario. The task of volunteers is to help disabled persons. We utilize the combinatorial auction mechanism to solve this task allocation problem. At this model, the volunteers are the bidders; the disabled persons are the items; and the emergency center is the auctioneer. The distance and health level of each disabled persons are used as the costs for the bids. When the rescue process starts, the emergency center creates a list of victims, sets the initial distance for victims, and broadcasts the information to all the volunteer agents. Only the volunteer agents whose distance to victims is less than the initial distance will help these victims. Each volunteer agent will only help the victims within the initial distance instead of helping all the victims. The initial distance will help volunteers in reducing the number of tasks that they have to do so that the decision making will be faster. The aim of this task allocation model is to minimize the evacuation time or the total cost to accomplish all tasks. In this case, the cost is the total rescue time.

1) The Criteria to Choose Disabled People

The volunteer's decision depends on the information of disabled people which receives from emergency center; therefore decisions must follow certain criteria to improve their relief activities.

For example, the volunteers must care about condition of disabled people; the more seriously injured people should have the more priority even if they locate further than the others. There are several criteria that volunteers should take in account before starting rescue process (Quang et al. 2009)

C1: Distance from volunteer to disabled people
C2: Distance from disabled people to nearest other disabled people
C3: Health level of disabled people
C4: Distance from disabled people to nearest other volunteer

Disabled people who have lesser values for criteria of C1, C2, C3 and greater values for criteria of C4 will have higher priority in the volunteer's decision process as shown in Figure 8.

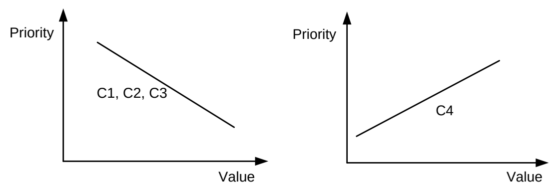


Fig. 8. Priority in the Volunteer's Decision

2) Determination Important Weight of Criteria

Referring to the our decision making method which presents at [23], a programming with C# had been created with the following inputs: number of criteria (N = 4); size of population (M = 30); crossover probability ($p_{cross} = 90\%$); mutation probability ($p_{mut} = 10\%$); number of reproduction (L = 100); the pair-wise comparison among criteria is shown in Table 4.8. The solution obtained is w = (0.2882, 0.2219, 0.2738, 0.2161). These values are also considered as input parameters for rescue simulation. It can be changed by adjusting the pair-wise comparison in Table 8.

For each volunteer, the cost to help certain victim is shown in Equation 1.

$$C(v)_k = \sum_{i=1}^{4} w_i * v_i^k \tag{1}$$

Where: w_i denotes the weight of the c_i criteria while v_i^k denotes the value of the i^{th} criteria for the k^{th} victim. The sign of value of criterion c_4 will be reversed when calculate the cost.

TABLE VIII. PAIR-WISE COMPARISON AMONG CRITERIA

Criterion	Linguistic Preference	Fuzzy Number	Criterion
C1	Good	(0.667, 0.833, 1)	C2
C1	Fair	(0.333, 0.5, 0.667)	C3
C1	Good	(0.667, 0.833, 1)	C4
C2	Poor	(0, 0.167, 0.333)	C3
C2	Fair	(0.333, 0.5, 0.667)	C4
C3	Good	(0.667, 0.833, 1)	C4

3) Forming Task Allocation Problem

Given the set of n volunteers as bidders: $V = \{v_1, v_2, \dots, v_n\}$ and set of m disabled persons considered as m tasks: $D = \{d_1, d_2, \dots, d_m\}$. The distances from volunteers to disabled persons; distances among disabled persons and health level of disabled persons and are formulated as follow:

$M[v_i, d_j]_t = \{m_{ij} \mid m_{ij}$: distances from volunteer v_i to disable person d_j at time step t$\}$

$N[d_i, d_j] = \{n_{ij} \mid n_{ij}$: distances from disabled person d_i to disabled person $d_j\}$

$H[d_i]_t = \{h_i \mid h_i$: health level of disabled person d_i at time step t; $h_{low} \le h_i \le h_{high}\}$

With the initial distance L. The normalization processes are shown in Equation (2), (3), (4).

Normalize $M[v_i, d_j]_t$:

$$M'[v_i, d_j]_t = \{m'_{ij} \mid m'_{ij} = (\frac{1-0}{L-0}(m_{ij} - 0) + 0); 1 \le i \le n;\ 1 \le j \le m\} \tag{2}$$

Normalize $N[d_i, d_j]$:

$$N'[v_i, d_j]_t = \{n'_{ij} \mid n'_{ij} = (\frac{1-0}{L-0}(n_{ij} - 0) + 0); 1 \le i \le n;\ 1 \le j \le m\} \tag{3}$$

Normalize $H[d_i]_t$:

$$H'[v_i, d_j]_t = \{h'_i \mid h'_{ij} = (\frac{1-0}{h_{high} - h_{low}}(h_i - h_{low}) + 0); 1 \le i \le m\} \tag{4}$$

The $Bid_{v_i}(\{d_j, d_q \dots d_k, d_l\}, C)$ means that the volunteer v_i will help victims $\{d_j, d_q \dots d_k, d_l\}$ with the total cost C. Total cost C is calculated by Equation 1.

Let I is a collection of subsets of D. Let $x_j = 1$ if the jth set in I is a winning bid and c_j is the cost of that bid. Also, let $a_{ij} = 1$ if the j^{th} set in I contains $i \in D$. The problem can then be stated in equation 5 (Sandholm 2002).

(4.1)
$$\min \sum_{j \in I} c_j x_j \quad \text{With constraint} \sum_{j \in I} a_{ij} x_j \le 1\ \forall i \in D \tag{5}$$

The constraint will make sure that each victim is helped by at most one volunteer at certain time step.

For example, let's assume that volunteer A has the information of 5 victims $(d_1, d_2, d_3, d_4, d_5)$. The initial distance is set to 200 meters. The volunteer estimates the distance from him to each victims and selects only the victims who are not more than 200 meters from his location. Assume that, the victim d_1 and victim d_2 are selected to help with the cost of 1.15. The bid submitted to the center agent is Bid_A= $(\{(d_1, d_2\}, 1.15)$.

This optimization problem can be solved by Heuristic Search method of Branch-on-items (Sandholm, 2002). This method is based on the question: "Which volunteer should this victim be assigned to?". The nodes in the search tree are the bids. Each path in the search tree consists of a sequence of disjoint bids. Each node in the search tree expands the new node with the smallest index among the items that are still available, not including the items that have already been used on the path. The solution is a path, which has minimum cost in the search tree. Figure 9 shows the procedure of task allocation problem for helping disabled persons in emergency situation.

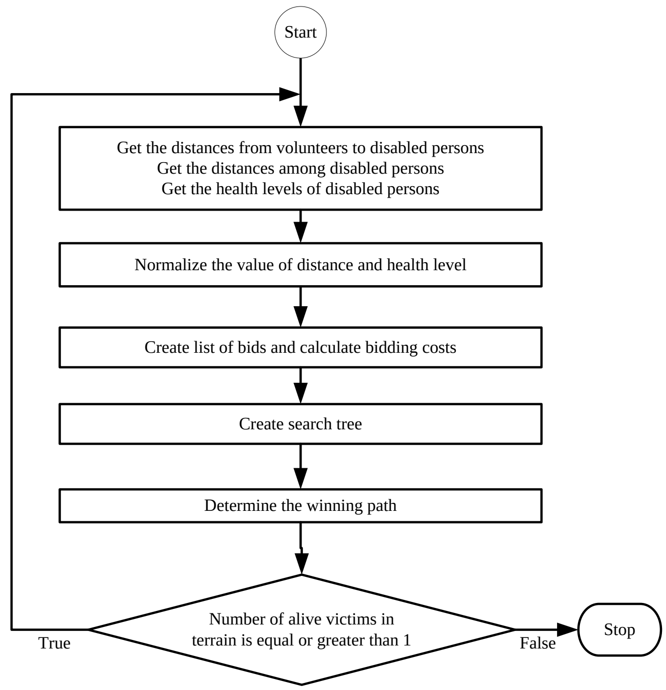


Fig. 9. Procedure of Task Allocation Problem

4) Example of Task Allocation Problem

To illustrate an example of a task allocation of volunteers to help disabled persons, let's assume that there are four volunteers and 3 disabled persons;

The initial distance L is set to 200 meters; $h_{low} = 100$; $h_{high} = 500$. At certain time of simulation, distances from volunteers to disabled persons, the distances among disabled persons, and the health level of disabled persons are assumed as follows.

$$\text{Before normalization } M[v_i, d_j]_t = \begin{bmatrix} 280 & 260 & 50 \\ 40 & 300 & 100 \\ 250 & 100 & 150 \\ 40 & 70 & 250 \end{bmatrix}$$

$$\text{After normalization } M'[v_i, d_j]_t = \begin{bmatrix} 1.4 & 1.3 & 0.25 \\ 0.2 & 1.5 & 0.5 \\ 1.25 & 0.5 & 0.75 \\ 0.2 & 0.35 & 1.25 \end{bmatrix}$$

$$\text{Before normalization } N[d_i, d_j] = \begin{bmatrix} 0 & 100 & 110 \\ 100 & 0 & 70 \\ 110 & 70 & 0 \end{bmatrix}$$

$$\text{After normalization } N'[d_i, d_j] = \begin{bmatrix} 0 & 0.5 & 0.55 \\ 0.5 & 0 & 0.35 \\ 0.55 & 0.35 & 0 \end{bmatrix}$$

$$\text{Before normalization } H[d_i]_t = \{400, 200, 300\}$$

$$\text{After normalization } H'[d_i]_t = \{0.75, 0.25, 0.5\}$$

With initial distance 200, the volunteer v_1 can help only victim d_3. The bid is formed as $B_{v_1}(\{d_3\}, C)$. There are four criteria with important weigh: w = (0.2882, 0.2219, 0.2738, 0.2161) [refer to section ii].

The cost C is calculated as below [refer to equation 1]:

Distance from volunteer v_1 to disabled people $d_3 = 0.25$

Distance from disabled people d_3 to nearest other disabled people $d_2 = 0.35$

Health condition of disabled people $d_3 = 0.5$

Distance from disabled people d_3 to nearest other volunteer $v_2 = 0.5$

$$C(v_1, d_3) = \sum_{i=1}^{4} w_i * v_i^3 = 0.2882 * 0.25 + 0.2219 * 0.35 + 0.2738 * 0.5 - 0.2161 * 0.5 = 0.18$$

Possible bids are listed as below.

$$B_{v_1}(\{d_3\}, 0.2882 * 0.25 + 0.2219 * 0.35 + 0.2738 * 0.5 - 0.2161 * 0.5) = B_{v_1}(\{d_3\}, 0.18)$$

$$B_{v_2}(\{d_1\}, 0.2882 * 0.2 + 0.2219 * 0.5 + 0.2738 * 0.75 - 0.2161 * 0.2) = B_{v_2}(\{d_1\}, 0.33)$$

$$B_{v_2}(\{d_3\}, 0.2882 * 0.5 + 0.2219 * 0.35 + 0.2738 * 0.5 - 0.2161 * 0.25 = B_{v_2}(\{d_3\}, 0.3)$$

$$B_{v_2}(\{d_1, d_3\}, 0.2882 * (0.5 + 0.55) + 0.2219 * (0.5 + 0.35) + 0.2738 * (0.75 + 0.5) - 0.216 * (0.2 + 0.25) = B_{v_2}(\{d_1, d_3\}, 0.74)$$

$$B_{v_3}(\{d_2\}, 0.2882 * 0.5 + 0.2219 * 0.35 + 0.2738 * 0.25 - 0.2161 * 0.35\ ) = B_{v_3}(\{d_2\}, 0.21)$$

$$B_{v_3}(\{d_3\}, 0.2882 * 0.75 + 0.2219 * 0.35 + 0.2738 * 0.5 - 0.2161 * 0.25 = B_{v_3}(\{d_3\}, 0.38)$$

$$B_{v_4}(\{d_1\}, 0.2882 * 0.2 + 0.2219 * 0.5 + 0.2738 * 0.75 - 0.2161 * 0.2 = B_{v_4}(\{d_1\}, 0.21)$$

$$B_{v_4}(\{d_2\}, 0.2882 * 0.35 + 0.2219 * 0.35 + 0.2738 * 0.2 - 0.216 * 0.5) = B_{v_4}(\{d_2\}, 0.14)$$

$$B_{v_4}(\{d_1, d_2\}, 0.2882 * (0.2 + 0.5) + 0.2219 * (0.5 + 0.35) + 0.2738 * (0.75 + 0.25) - 0.21 * (0. + 0.35)) = B_{v_4}(\{d_1, d_2\}, 0.55)$$

The possible bids with costs are shown in Table 9.

TABLE IX. POSSIBLE BIDS WITH COSTS

Bid	Volunteer	Disabled person	Cost
b_1	v_1	$\{d_3\}$	0.18
b_2	v_2	$\{d_1\}$	0.33
b_3	v_2	$\{d_3\}$	0.30
b_4	v_2	$\{d_1, d_3\}$	0.74
b_5	v_3	$\{d_2\}$	0.21
b_6	v_3	$\{d_3\}$	0.38
b_7	v_4	$\{d_1\}$	0.33
b_8	v_4	$\{d_2\}$	0.14
b_9	v_4	$\{d_1, d_2\}$	0.55

The bid b_2 and b_7 have the same task $\{d_1\}$; b_5 and b_8 have the same task $\{d_2\}$; b_1, b_3, and b_6 have the same task $\{d_3\}$. The more expensive bids will be removed as shown in table 10.

TABLE X. TASKS ALLOCATION AND COST AFTER REMOVAL OF MORE EXPENSIVE BIDS

Bid	Volunteer	Disabled person	Cost
b_1	**v_1**	**{ d_3}**	0.18
b_2	**v_2**	**{ d_1}**	0.33
b_4	**v_2**	**{ d_1, d_3}**	0.74
b_8	**v_4**	**{ d_2}**	0.14
b_9	**v_4**	**{ d_1, d_2}**	0.55

Then, the search tree is formed as shown in Figure 10. The winner path is b_2, b_8, b_1 which has the most minimum cost of 0.65. The task allocation solution: volunteer v_2 will help disabled persons d_1 ; volunteer v_4 will help disabled person d_2.volunteer v_1 will help disabled person d_3.

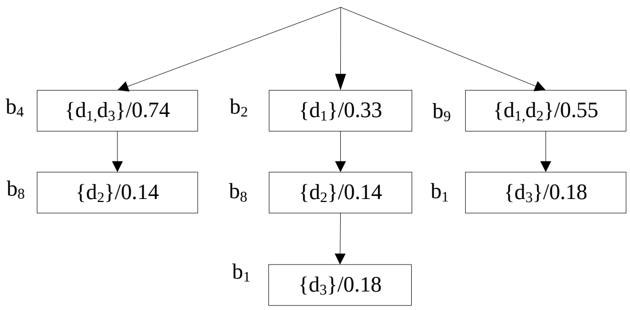


Fig. 10. Branch on Items Based Search Tree

D. Path finding in Gama Simulation Platform

After a volunteer makes the decision to help a certain victim, the path finding algorithm is used to find the route from volunteer agent to victim agent. The GIS data presents roads as a line network in graph type. Figure 11 shows an example of graph computation. The Dijkstra algorithm is implemented for the shortest path computation [8].

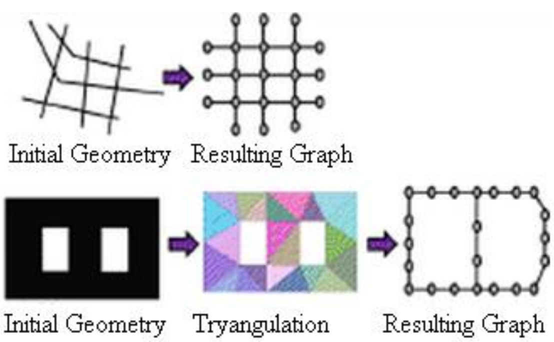


Fig. 11. Example of Graph Computation [8]

IV. EXPERIMENTAL RESULTS

In this section, we present experimental studies on different scenarios. We show the experimental results with traditional rescue model which not considering the updated information of victims and volunteers such as health conditions, locations, traffic conditions.

The traditional rescue model provides fixed mission for which volunteers should help which victims. Whereas, our rescue model provides flexible mission for which volunteers should help which victims. The targets of volunteers can be changed dynamically according to current situation. The experimental results of our proposed rescue model are also presented to show the advantages comparing to traditional model.

The evacuation time is evaluated from the time at which the first volunteer started moving till the time at which all saved victims arrive at the shelters. The simulation model is tested using the Gama simulation platform [8, 10].

A. Experimental Setting

We consider the number of volunteers, number of disabled persons, panic level of volunteer, disability level of victim and the complexity of traffic as parameters to examine the correlation between these parameters with rescue time. The traffic complexity is function of the number of nodes and links in a road network.

Figure 12 presents the sample GIS map consisting of 4 layers: road, volunteer, disabled person and shelter. The initial health levels of disabled persons are generated randomly between 100 point and 500 point. If the health level is equal or less than zero, the corresponding agent is considered as dead.

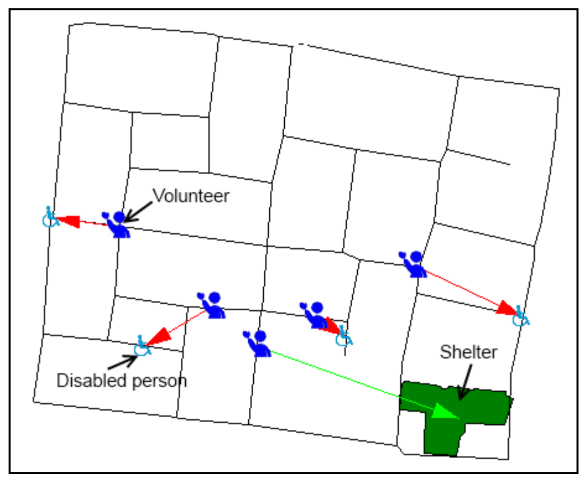


Fig. 12. Sample Gis Map of Disaster Space

B. Experimental results

1) Comparison with traditional model

The traditional model proposes the rescue process without knowing the updated information of victims and volunteers. In disaster space, the traffic condition is changed dynamically. Some road links can be inaccessible.

Our proposed method provides the updated traffic condition so that the path finding method can work effectively. The road map with 50 links is used to conduct the test with traditional model and our proposed model. The result is shown in Table 11 and Figure 13, 14.

TABLE XI. COMPARISON WITH TRADITIONAL MODEL

	Volunteer	**Victim**	**Link**	**Rescue Time**	**Dead Victim**
Proposed Model	10	10	50	880	0
Traditional Model	10	10	50	1300	1

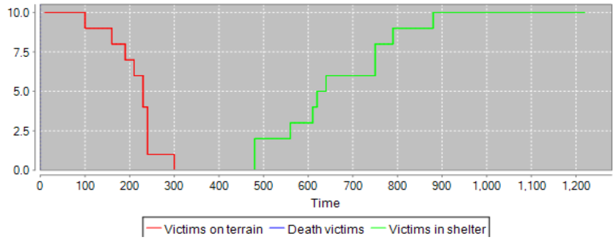


Fig. 13. Rescue Time with Proposed Model

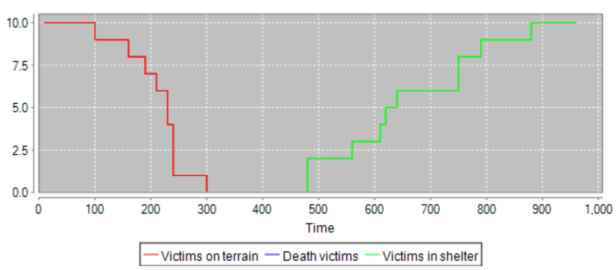
Fig. 14. Rescue Time with Traditional Model

2) Simulation result with consideration of complexity of road network

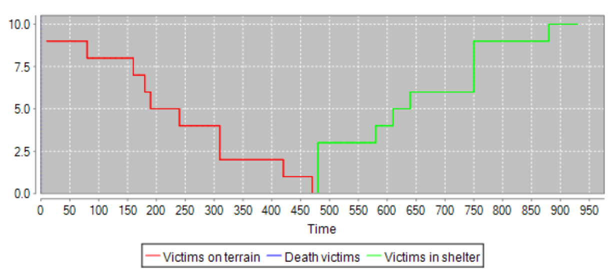
In this concern, we observe the correlation between the complexity of road network and the rescue time. The area of disaster space, the number of victims and volunteers, locations of victims and volunteer are not changed. The complexity of road network presents as the number of road links. The result is shown in Table 12 and Figure 15.

TABLE XII. RESCUE TIME AND NUMBER OF LINKS

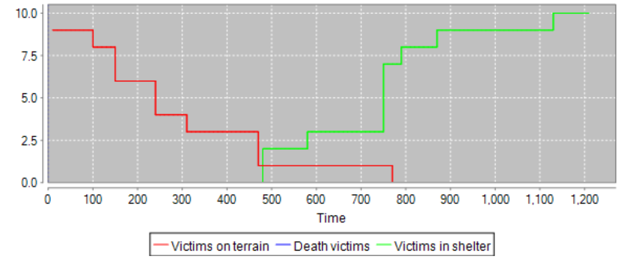
Volunteer	Victim	Link	Rescue Time	Dead Victim
10	10	50	880	0
		40	880	0
		30	1150	0
		20	1150	0



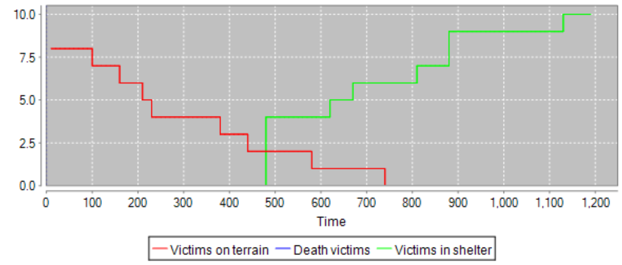
Link: 50 Rescue time: 880



Link: 40 Rescue time: 880



Link: 30 Rescue time: 1150



Link: 20 Rescue time: 1150

Fig. 15. Correlation between Rescue Time and Number of Link

The rescue time increase if number of link decrease at the same area of disaster space.

3) Simulation result with consideration of panic level of volunteer

When emergency situation occurs, the volunteers are also getting panic. The panic probability of volunteers can be presented as the hesitance of volunteers in making decision to help disabled persons. In the simulation, we assume that there are 10 levels of hesitance: 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9. The hesitance level 0 means that there is no hesitance of making decision. These hesitance levels will be assigned to every volunteer agent. At each time step of simulation, a random value x ($0<x<1$) will be generated. If x is equal or greater than hesitance level of volunteers, the corresponding volunteers will make decision to help disabled person; otherwise the volunteers will postpone the decision at this time step.

We applied our method to a sample GIS road map with 50 links (Figure 12). The correlation between panic probability of volunteer and rescue time is shown in Table 13 and Figure 16.

TABLE XIII. SIMULATION RESULTS WITH CONSIDERATION OF PANIC PROBABILITY OF VOLUNTEER

Volunteer	Victim	Link	Panic Level	Rescue Time	Dead Victim
10	10	50	0	880	0
			0.1	900	0
			0.2	1150	0
			0.3	1150	0
			0.4	1500	1
			0.5	1750	1
			0.6	1760	1
			0.7	2200	1
			0.8	2600	2
			0.9	3250	3

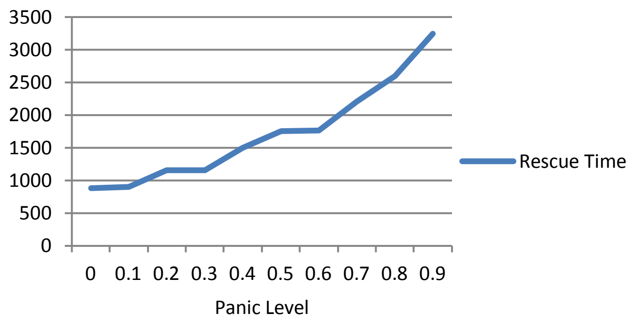


Fig. 16. Simulation Results with Consideration of Panic Level of Volunteer

4) Simulation result with consideration of block lane percentage of road network

When emergency situation occurs, the road lane may block. The road is set as inaccessible condition if its number of block lanes is equal to the number of lanes. In the simulation, we assume that there are 10 levels of block road: 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9. The correlation between the percentage of block road link, the rescue time and the number of dead victim is shown in Table 14 and Figure 17.

TABLE XIV. SIMULATION RESULT WITH CONSIDERATION OF BLOCK LANE PERCENTAGE OF ROAD NETWORK

Volunteer	Victim	Link	Percentage of block road	Rescue Time	Dead Victim
10	10	50	0.1	950	0
			0.2	1000	0
			0.3	1050	0
			0.4	1200	0
			0.5	1325	1
			0.6	1700	1
			0.7	2300	1
			0.8	2700	3
			0.9	3450	4

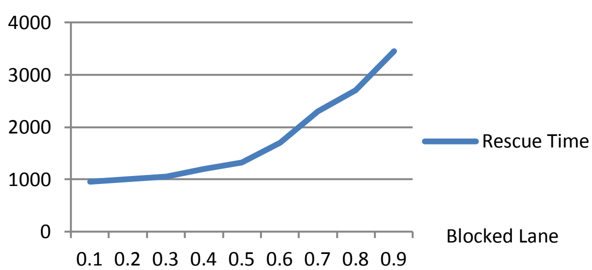


Fig. 17. Simulation Results Result with Consideration of Block Lane Percentage of Road Network

5) Simulation result with consideration of disability level of victim

The disability level of victim may affect to the rescue process. In order to facilitate the simulation, we assume that there are two level of disability: low and high. The victims, who have higher level of disability, will reduce the health level faster than victims, who have lower disability level. The correlation between the percentage of disability level of victim, the rescue time and number of dead victim is shown in Table 15 and Figure 18.

TABLE XV. SIMULATION RESULT WITH CONSIDERATION OF PERCENTAGE OF HIGH DISABILITY LEVEL

Volunteer	Victim	Link	Percentage of High Disability Level	Rescue Time	Dead Victim
10	10	50	0.1	880	0
			0.2	890	0
			0.3	1050	0
			0.4	1050	1
			0.5	1125	1
			0.6	1250	2
			0.7	1325	3
			0.8	1450	4
			0.9	1550	5

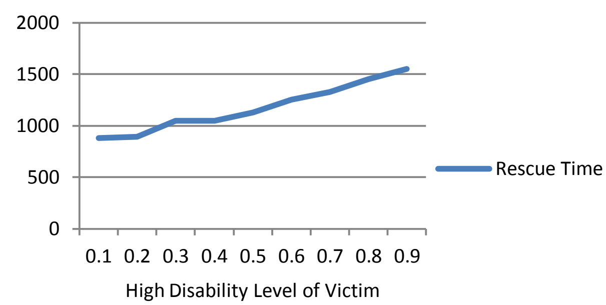


Fig. 18. Simulation Result with Consideration of Percentage of High Disability Level

6) Simulation result with consideration of disconnectivity between agent and emergency center

In reality, when emergency situation occurs, the communication among objects may have problem. This problem of communication will affect to the rescue process. In simulation, we simulate the disconnectivity by postponing the decision of volunteer for certain number of time steps. The result is shown in Table 16 and Figure 19.

TABLE XVI. SIMULATION RESULT WITH CONSIDERATION OF DISCONNECTIVITY BETWEEN AGENT AND EMERGENCY CENTER

Volunteer	Victim	Link	Disconnectivity	Rescue Time	Dead Victim
10	10	50	10	960	0
			20	980	0
			30	1000	0
			40	1020	0
			50	1050	0
			60	1060	0
			70	1075	0
			80	1085	0
			90	1115	1

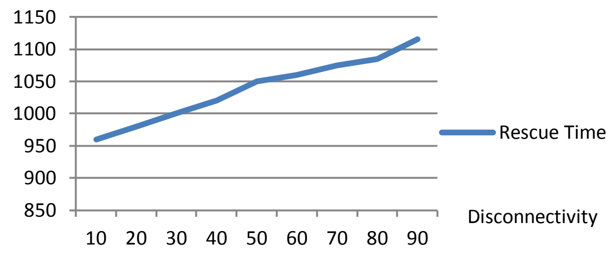


Fig. 19. Simulation Result with Consideration of Disconnectivity between Agent and Emergency Center

V. CONCLUSION

In this paper, we propose a rescue model for people with disabilities. The decisions to help victims are based on updated information from victims and volunteers therefore it can be change to adapt the current emergency situation.We also conduct the rescue simulation with considering the complexity of road network, the panic level of volunteers, the disability level of victims and the disconnectivity between agent and emergency center. The simulation results show that our model has less rescue time than traditional model which applies static decision making method.

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