Optimizing Smartphone Recommendation System through Adaptation of Genetic Algorithm and Progressive Web Application

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***Abstract*—The ubiquity of smartphone use nowadays is undeniable exponentially growing, replaced cell phones, and a host of other gadgets replaced personal computers to a certain degree. Different smartphones specifications and overwhelmed smartphone advertisements have caused broader choices for the customer. Many qualitative and quantitative criteria need to consider, and customers want to select the most suitable smartphones. They face difficulties deciding the best smartphone according to their budget and desire. Thus, a new method is needed to recommend the customer according to their preferences and budget. This study proposed a method for optimizing the recommendation system of the smartphone using the genetic algorithm (GA). Moreover, it is implemented with a progressive web application (PWA) platform to ensure the customer can use it on multiple platforms. They can choose the platform to input any specification of smartphone preferences besides the budget. Functional testing results showed the achievement of the study's objectives, and usability testing using UEQ managed to receive feedback of 93.64%, with an overall average mean of 4.682. Therefore, according to the outcome, it can be concluded that optimizing the smartphone recommendations through GA enables the customer to ease the comparison based on the obtained optimum result.**

Keywords*—Genetic algorithm; progressive web application; recommendation; smartphone introduction

I. Introduction

In this modern era, smartphones are one of today's most necessary and personal technologies [1]. Smartphones can drastically alter how humans communicate, consume information consumption, and use their time. Smartphones are used to make calls, read or send emails, view and upload images and videos, play games, and listen to music [2]. Besides, it reacts as a personal diary to record reminders or schedules and contacts, browses the internet, speech searching, verify the latest news update and the current or predicted climate. It also uses text chatting applications such as Facebook, Twitter, and WhatsApp and connects on social networks [3].

The selection of smartphones compatible with consumers' needs has motivated our research topic. Molinera et al. [4] claimed that whenever it comes to purchasing a new smartphone model, customers can easily get lost in the midst of hundreds of advertisements from different companies. We have surveyed 100 respondents, and it shows that 89% of respondents have trouble choosing the right smartphone. Also, 94% of respondents of the same survey claimed that it is more convenient to recommend a list of smartphones within their budget and preferences. Furthermore, they were having difficulties comparing the preferences of the smartphone features within the budget. They have to search manually through dozens of reviews on the overwhelming information on the internet. 77% of respondents claimed that they read reviews or comment on the smartphone before making a decision. It is time-consuming and puts much effort into cognitive while manually searching the rating and feedback based on user preferences [5]. The consequences of relying on reviews will be a combination of negative and positive feedback, and consumers feel difficult to seek a cogent response. Besides, the unauthorized review may be a scam too.

Nonetheless, most comparison approaches use the specific meaning of the attribute. Sometimes, customers may not accurately describe the artifacts in which they are interested. They do not entirely understand the level or degree of specific attributes and hard to locate a precise analysis for a specific service feature [6]. The recommendation of the product's latest features in an adaptive manner is not successful due to the high-end products' short life cycles. It has caused inappropriate reviews and obsolete scores rated by other users [7].

Sponsored by Indonesian Ministry of Research and Technology and Universitas Pendidikan Indonesia.

Cha & Seo [8] claimed an average of 54% estimated that 21 developing and emerging countries such as Malaysia, Brazil, and China had at least one internet or smartphone by 2015. The ubiquity of smartphone use nowadays is undeniable exponentially growing. Smartphones have become a host of other gadgets, replaced cell phones, to a certain degree, replaced personal computers [9]. In 2017, 5 billion individuals possessed smartphones, and by 2025, this number is predicted to rise to 5.9 billion. 95% of the population in the United States owns a smartphone. Through new features, smartphones are constantly evolving, becoming cheaper and faster each year at the same time. Therefore, it is essential to consider the quality and quantitative requirements to select the most preferred smartphones. For example, pixel density, the camera resolution, RAM, battery power, stand-by time, memory built-in, weight, thickening, scaling, type of the processor, processor, and costs are quantitative parameters. In the meantime, consistency requirements include longevity, reliability, aesthetics, and branding. Thus, Chen et al. [10] indicated that customers' purchasing decisions are different because their perceptions and desires vary. Customers would feel satisfied with the criteria leading to an informed decision to make one-hand purchases and meet their expectations.

Now-a-days, humans have been very dependent on mobile phones since developing robust mobile applications. Besides, mobile applications thrived originally aimed for productivity assistance and information retrievals such as emails, calendars, and contact databases. Due to the rapid advancement of technology and public demands, it is essential to implement an effective development of mobile applications as there is a need to overcome many challenges [11]. Unfortunately, every invention comes with limitations where mobile applications need to be compatible with the platform of the devices to work.

As a solution, in this study, the system will be a progressive web application (PWA) which is application software that can cross any platform. This enhancement of PWA does not force users to download the application to experience the features. However, the functionality remains the same [12]. Besides, this recommended system research optimization technique focuses on adapting a GA. The selection method works by using each member's fitness function according to the fitness value calculated. Resulting the fittest member is more likely to be selected based on the selection likelihood. This study outcome, SRcS, which stands for Smartphone Recommendation System, helps recommend which smartphone is affordable for the customer to purchase that follows customer preferences within the budget. This paper's organization begins with a brief introduction in Section 1. Section 2 explained the literature review and followed by methodology in Section 3. Section 4 elaborates on results and discussion. Finally, Section 5 concludes the study and briefly mentions future enhancement.

II. Literature Review

This section describes the smartphone preferences, recommendation technique, and progressive web application on the related issue.

A. Smartphone Preferences

A smartphone merged some electronic devices and became a miniature of a computer. It supports mobile or portable computing technology and applications with efficient operating systems [13]. The opportunities provided by the internet eventually makes smartphones often provide qualitatively different service. Smartphone has become a part of human life basic needs nowadays. Rotondi et al. [14] claimed that the smartphone's advent has significantly changed how information is accessed, allocated time, and interacted with others. The consumer's decision-making process depends on the product attributes. Price is the most obvious concerning the attribute of smartphones [15]. Due to that, a smartphone's price plays a vital role in a company's market strategy. Customers will also compare their needs and want between various products to buy their products inside their budget fit [16]. Therefore, the product quality must match the price to find that it is worth investing in a smartphone.

Next, consumers' need for multi-function cell phones drives the smartphone's development [17]. There are plenty of platforms for development, but the two famous and excellent platforms are iPhone Operating System (iOS) from Apple and Android from Google. Up until now, Android and iOS remain to dominate the market share of smartphones worldwide. Despite that, the Android operating system is considerably newer than iOS. Android utilizes iOS weaknesses and promotes a tangible cross-platform development operating system [18].

Furthermore, [19] agreed that organizations will always find ways to be different, especially in the smartphone industry, which continuously changes technology. The brand name can be an organization's brand and exclusivity. The brand name can be a title, word, logo, and design to differentiate its rivals such as Acer, Amazon, Apple, Samsung, BlackBerry, Nokia, Huawei, Lenovo, Microsoft, One Plus, Oppo, ZTE and Sony, and. Marketers were trying to create brand equity to improve customer response to win consumer preference and loyalty. Brand equity represents how the brand thinks, feels, and behaves. Thus, it becomes the products and services value-added [20].

Smartphones will only become more and more popular. Most people depend on their mobile devices to run their lives nowadays. Thus, smartphone brands need to thoroughly understand the current use and future adoption. The brand presence is essential, as it ensures that the business has a specific role in the markets and has established its reputation in the consumer's view [21]. However, [22] claimed that choice depends on the consumer's different variables, calculated by the utility. This proposed project focuses on the top five smartphone model brands in Malaysia: Samsung, Vivo, Oppo, Huawei, and Xiaomi. Purwanto [23] revealed a study outcome during the covid 19 pandemic where sales promotion and brand image influenced smartphone purchasing.

Besides, there are many high technology smartphones features available in the market today. Therefore, different individuals can choose a specific smartphone to meet their needs and desires—the smartphone features, including software and hardware. Hardware is a system concept that can

be physically touched; meanwhile, software, for instance, computer programs, procedures, and documentation are the general terms. Hardware is the smartphone's size, design, color, body, and weight, whereas software consists of the documentation and application. Rahman et al. [24] alleged that many consumer choices could be rational, such as time management, communication, and emotional, such as camera, games, music, and application features.

Cost, reliability, battery's lifespan, special promotions, camera resolution, size, storage offered, networking, or connectivity options affect customers' features when purchasing any smartphone. People believed that the smartphone's size connects with the screen's resolution and is inversely linked, such as the bigger the phone, the higher the resolution, and the harder it to carry. Therefore, with the enormous open doors within a short period in the smartphone showcase, smartphone suppliers need to understand factors that satisfy the customer decisions on which model to buy [25]. All of these demands in preferences become the input. Then, the system processed the algorithm and produced a list of smartphones that matched the most input preferences.

B. Recommendation Technique

Artificial intelligence (AI) approaches have become more prevalent in a variety of fields. For instance, recommender systems provide consumers with recommendations for selecting different items from a massive pool of items [26]. Consequently, it creates a program that can allow people to select requirements and remove the dilemma. Numerous options allow humans to be uncertain about what is best for them or fulfil their needs. The recommendation helps customers reduce the time and difficulty of searching for the information required. The methods promote customers towards the product by collecting and evaluating feedback from other buyers, implying reviews from specific establishments and even the customer [27].

Consequently, many new researchers have embarked on this study to develop more recommended research and techniques. Several techniques have been evaluated based on the accuracy, ability to receive multiple inputs, and simplicity—for instance, fuzzy logic, content-based filtering, and genetic algorithm. Table I explains the details of the comparison.

TABLE I. FEATURES COMPARISON BETWEEN RECOMMENDATION TECHNIQUES

Technique / Features	**Content-Based Filtering**	**Fuzzy Logic**	**Genetic Algorithm**
Accuracy	Medium	Low	High
Receive many inputs and run in a single run	Yes	No	Yes
Simplicity	No	No	Yes

In conclusion, GA has been chosen because simple programmability and efficiency features offered. GAs is a robust optimization system widely applicable since it requires users to give many inputs to run in a single run [28]. The GAs maintained the population of an individual's chromosomes along with their fitness scores. It gave more opportunities for individuals with better fitness scores to reproduce than others. Thus, GA can give the best optimization solution to the smartphone buyer. No matter what the user may input into the system, GA will always provide one recommendation instead of null.

C. Progressive Web Application

PWA is an abbreviation for Progressive Web Application. It is also a cross-platform with a new approach that modern web capabilities provide a user experience. PWA uses the most recent technology to incorporate the best of web and mobile apps. PWA hence unifies the browsing web experience on mobile and other devices of various pixel sizes, including laptops, tablets, and other devices [29]. The web-based framework is designed using HTML, CSS, and JavaScript standards. It is compatible with any platform that supports standards-compliant browsers. Besides, the PWA development and evolution is not a new framework or technology. It allowed the mobile expansion externally for cross-platform [30]. With the advantage of a mobile app's features, PWA enhances user retention and execution without complicating a mobile application's maintenance. Biørn-Hansen et al. [31] declared that the service worker sits at the heart of a PWA because, without a service worker, support will cause PWA not to work correctly. A service worker helps give the consumers of a web application an offline experience. A service worker is a client-side script that operates on a different JavaScript thread and is independent of the web application. It helps developers programmatically store and preload data so that the code can be loaded from the user cache if the network connection fails.

Furthermore, PWA requires a manifest file. The JSON file is the manifest file for the web application that applies to the user-installable home screen. A manifest file configures the application includes name, short name, icons, background color, view, width, and theme color. It manages to change the behavior and design of PWA. The PWA platform adapts in developing this recommendation system because it is understandable, reliable, and faster to access. Besides, PWA is a regular application on a computer. The ability to run it from a uniform resource locator (URL) makes it easy for users with a browser to use the program [32]. Therefore, it is unnecessary to maintain an application programming interface (API) with backward compatibility. Each user uses the same website version of the code, unlike the version fragmentation of native apps, making it easier to deploy and manage the software. Meanwhile, web-based information systems offer easy and cost-efficient resources to facilitate usability, effective delivery, efficient administration, and cross-platform versatility.

III. METHODS

Four subsections describe the flow in implementing the proposed idea: system use case, system flowchart, the phases of GA implementation, and PWA implementation.

A. System use case for SRcS

The overall system use case illustrated in Fig. 1 demonstrates using the UML on users' interaction. We identify ten use cases for this system: seven use cases handled by the admin and three by the user.

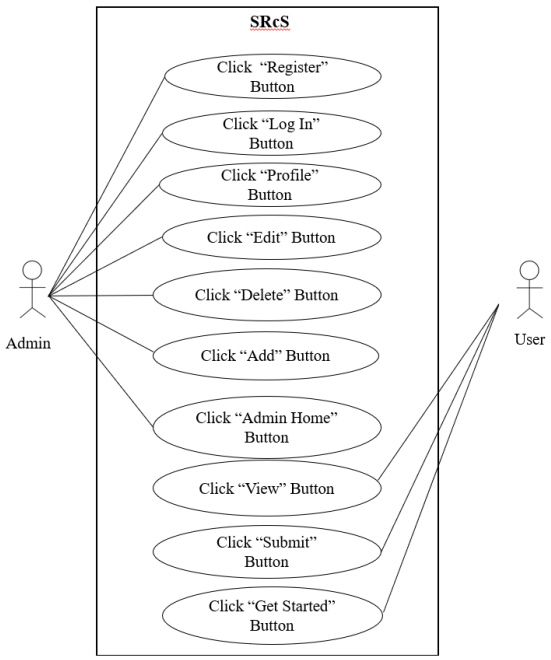

Fig. 1. SRcS use Case Diagram.

B. Flow Chart for SRcS

A visual representation of the series of steps and decisions or a flowchart requires a system using different symbols containing information. It is essential in design phases to avoid any obstacle and clearly describe the system. The flow of the recommendation process for SRcS shown in Fig. 2. The user must provide 16 specifications of their preferences into the system, including the budget. The chosen specification will then go through the five GA processes to get the smartphone's highest match with the user's input. Lastly, resulting in the top three smartphone recommendation lists.

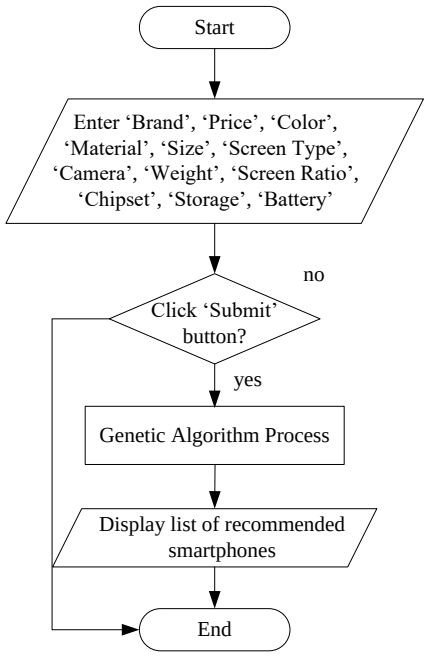

Fig. 2. Process flow for SRcS.

C. Genetic Algorithm Implementation

As mentioned, GA involves five processes that start with initializing the population, followed by fitness calculation, crossover, mutation, and convergence. All user information is stored in the system as input. This sub-section presented a detailed description of each process involved and how GA produces the final result. Fig. 3 shows the basic process of GA, which consists of six main steps: 1) initialize population, evaluate fitness, 2) create a new population through the selection of the individuals, 3) process the crossover and mutation, 4) test the condition and if satisfied, return the best individual of the current population. Else, repeat the process.

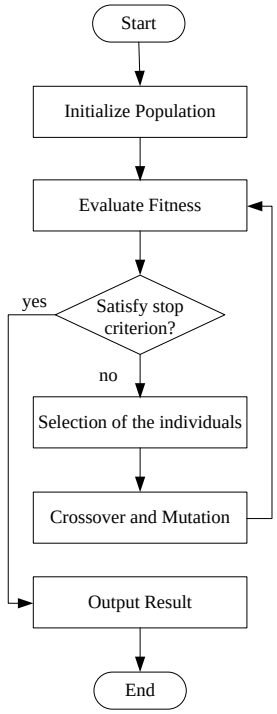

Fig. 3. Process for Genetic algorithm

1) Step 1: Initialize population: GA begins with an initial population of typically randomly formed phenotypes. The GA needs to continue to evolve new genotypes from the population and evaluate each genotype's fitness at each iteration. The population will create chromosomes up to 150 generations as their stopping condition is defined in for loop. Each chromosome encodes three types of smartphones. Each smartphone contains information like the brand, price, colour, material, size, year release, display, camera, weight, chipset, CPU, GPU, RAM, memory, and battery, as in Fig. 4.

2) Step 2: Evaluate fitness: The next phase is calculating each chromosome's fitness by comparing the user with database chromosomes. Each smartphone holds an equal percentage of totalling 100%. The fitness function is the inverse of the input given, for example, using three variables: a, b, and c. Fitness means the best result for the input given for a, b and c, so we can assume the value will be d as in (1).

$$a + b + c = d \quad (1)$$

Smartphone23	Smartphone67	Smartphone09	Fitness
Brand	Brand	Brand	
Price	Price	Price	
Color	Color	Color	
Material	Material	Material	
Size	Size	Size	
Release Year	Release Year	Release Year	
Screen Type	Screen Type	Screen Type	
Camera Number	Camera Number	Camera Number	
Rear Camera	Rear Camera	Rear Camera	
Front Camera	Front Camera	Front Camera	
Weight	Weight	Weight	
Resolution	Resolution	Resolution	
Chipset	Chipset	Chipset	
GPU	GPU	GPU	
RAM	RAM	RAM	
Storage	Storage	Storage	
Battery Capacity	Battery Capacity	Battery Capacity	
Battery Type	Battery Type	Battery Type	

Fig. 4. Chromosome Encoding.

The process of fitness function declares as the inverse of | a + b + c – d | because of the need to reduce the sum of the three variables from deviating from d. Thus, the fitness function identifies as in (2).

$$\text{Fitness Function} = 1/ | a + b + c - d \quad (2)$$

3) Step 3: Crossover and mutation: After calculating the value of fitness, the best fitness value is chosen and arranged to descend from the highest fitness-to-lowest. The crossover and mutation operation uses the first three highest fitness values for chromosomes. Then, it follows by sorting out the fitness value. Fig. 5 shows the crossover example between chromosome X and Y. The GA process chooses and displays the highest fitness value data to the user.

D. Progressive Web Application Implementation

A PWA requires a web manifest and service worker file. The manifest file allows the system to execute the full-screen web application as a standalone application. It can assign an icon to show when finishing the application and assign a theme and background colour app on the computer. Furthermore, this application also has implemented an installation banner that makes it easier to be download on any device.

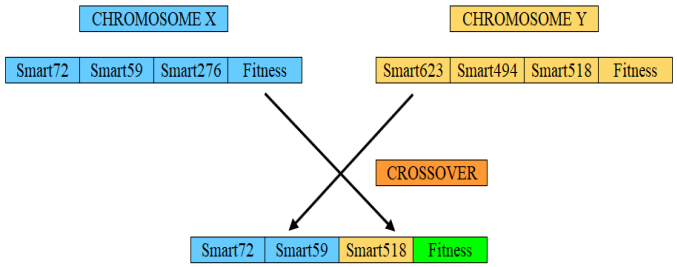

Fig. 5. Example of Crossover Process.

Next, service workers are the mastermind of PWA, in which it reacts as middleware by intercepting each request. It responds instantly to the cached request or performs the channel recovery. There are two caches implemented in this system, which are dynamic and static. In static stores, every single asset while in dynamic fetches all previously requested assets while users online limit to 20 requests to be stored. Inside service worker also implements install and activate event code. An event code fires when the service worker is mounted and occurs once. If the service worker is installed and activated, the device will use the currently installed service worker. The caches are deleted whenever there are changes to cache the latest version of code. Therefore, every declared asset will be cached automatically.

E. Evaluation and Acceptance

In this study, two types of tests were performed, which are testing on functionality and usability. Functionality evaluation is testing to verify the outcome for each use case module. Every module is evaluating whether it could generate the predicted result. Usability testing is about bringing actual people to connect with the system and watch their behavior and reactions. The key benefit of usability testing is to detect usability problems with a design as early as possible before the design is adopted. This step ensures that the program built is convenient for someone with no computer science experience to use. Therefore, we do the evaluation using the User Experience Questionnaire (UEQ). UEQ is a quantitative survey proposed by [33] [34], and we test it according to the SRcS functionality. UEQ consists of 26 dimensions, but we chose five dimensions related to the study as in Table II.

TABLE II. FIVE UEQ DIMENSION AND DESCRIPTION FOR USABILITY TEST

Dimension	Description
Attractiveness	Overall impression of the product. Do users like or dislike the product?
Perspicuity	Is it easy to get familiar with the product? Is it easy to learn how to use the product?
Efficiency	Can users solve their tasks without unnecessary effort?
Usefulness	Is it useful? Helpful? Beneficial? Rewarding using the application?
Novelty	Is the product innovative and creative? Does the product catch the interest of users?

Our research respondents consisted of 30 public participants who randomly took part in the application testing. Firstly, we briefed the participants on project details and what they were required to do with the application. Then they tried the application until they were satisfied with the recommendation given by the system. Once they finished it, we issued the UEQ using the Google Form.

IV. RESULTS AND DISCUSSION

A. Functionality Testing

Functionality evaluation is testing to verify the outcome for each use case module. Every module is evaluating whether it could generate the predicted result. Fig. 6 and Fig. 7 indicate the SRcS snapshot, the user filling up the form with the questions that began with the brand, price, and specification preferences question. Then, SRcS shows the user's smartphone recommendation result, as in Fig. 8.

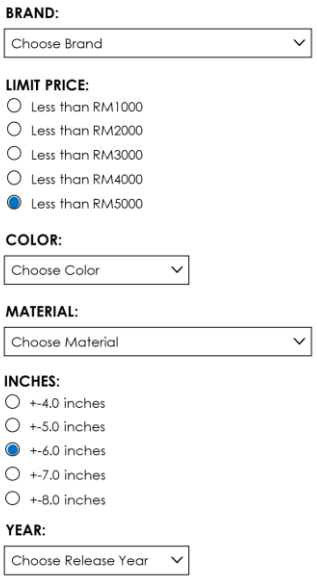

Fig. 6. Snapshot of SRcS submenu 1

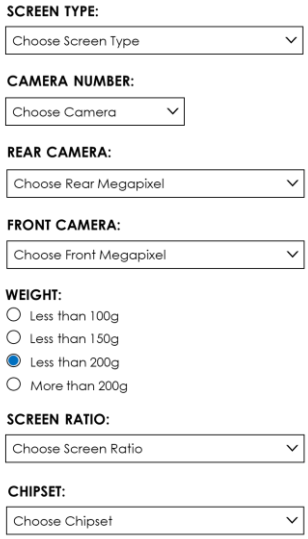

Fig. 7. Snapshot of SRcS submenu 2

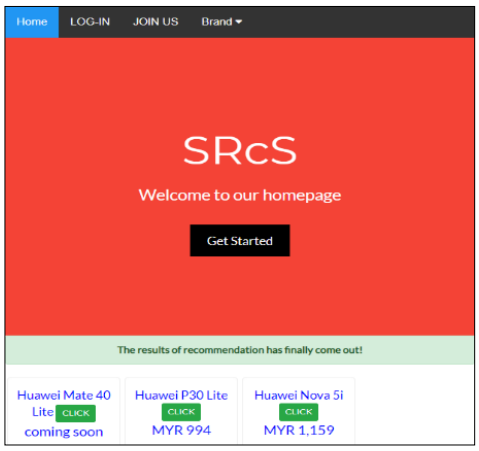

Fig. 8. SRcS recommendation result

The evaluation of the functionality test follows according to the use case of SRcS, and Table III displays the SRcS outcome on the functionality test to ensure that it works according to the proposed.

TABLE III. SRCS FUNCTIONALITY TEST RESULT

Use Case	Description	Remark
Register Button	Allows a new admin to register into the system	Successful
Log In Button	Allows admin to log in to the profile page	Successful
Profile Button	Allows admin to view their account information	Successful
Edit Button	Allows admin to update their account information	Successful
Delete Button	Allows admin to delete smartphone details system	Successful
Home Button	Allows both user and admin to view all smartphones available in the database	Successful
Find Button	Allows both users to find a smartphone that matches with user's preferences	Successful
Profile Button	Allows admin to view their account information	Successful

B. *Usability Testing*

We evaluate the feedback given by the 30 respondents and summarize the UEQ results for the five items. Each of the dimensions has a related and specific questionnaire to get a quantified value. Table IV shows the overall average value of the UEQ with the specific result for mean and average mean.

For the first dimension attractiveness, feedback shows that respondents felt that the SRcS shows the highest average mean of 4.800 for four questionnaires that asked whether the application is enjoyable, good, pleasant to use and user friendly. Item A2 get the highest average mean among the rest dimension with 4.933, and we get direct feedback that the application is good. Item A4 get the lowest average mean of 4.667 for the first dimension due to not all specification being well-known by some respondents. We further analyze the second dimension, perspicuity, which is related to the ease of using the application with an average mean score of 4.711. We guest the same issue for item P2 with A4, where not all users have deep knowledge about the smartphone specification. Dimension three is dependability asked on the application's reaction to the user input, whether predictable and meets expectations. Item D1 gets the lowest mean among the rest with 4.433, but item D2 shows a contra result that the input and command meet the user's expectations. The fourth dimension is related to the usefulness of the application. Item U1 until U3 managed to get the result more than 4.500 mean with the average mean of 4.750. We can assume that the system is really useful to the respondents. The last dimension is novelty involved in the idea behind the application into four different criteria: creative, inventive, leading edge and innovative. Although we got the lowest mean for item N3, we managed to get an average mean of 4.533, which is more than 4.500. In summary, the average overall mean score for SRcS is 4.682 or 93.64% conclude that the system considers received a 'High' level of usability acceptance.

TABLE IV. MEANS, STANDARD DEVIATION AND CONFIDENCE INTERVALS UEQ FOR SRCS

Dimension	Item	Question	Mean	Average Mean
Attractiveness	A1	In your opinion, the application is enjoyable	4.767	**4.800**
	A2	In your opinion, the application is good	4.933	
	A3	In your opinion, the application is pleasant to use	4.833	
	A4	In your opinion, the application is user friendly	4.667	
Perspicuity	P1	In your opinion, the application is easy to understand	4.833	**4.711**
	P2	In your opinion, the application is easy to learn	4.533	
	P3	In your opinion, using the application is easy	4.767	
Dependability	D1	In your opinion, the reactions of the application to your input and command is predictable	4.433	**4.617**
	D2	In your opinion, the reactions of the application to your input and command meets expectations	4.800	
Usefulness	U1	You consider using the application as useful	4.533	**4.750**
	U2	You consider using the application as helpful	4.767	
	U3	You consider using the application as beneficial	4.867	
	U4	You consider using the application as rewarding	4.833	
Novelty	N1	In your opinion, the idea behind the application and the designs are creative	4.567	**4.533**
	N2	In your opinion, the idea behind the application and the designs are inventive	4.500	
	N3	In your opinion, the idea behind the application and the designs are leading edge	4.433	
	N4	In your opinion, the idea behind the application and the designs are innovative	4.633	
Average Overall Mean Score			**4.682**	
Average Percentage of Mean Score			**93.64%**	

V. CONCLUSION

This study aims to develop a smartphone recommendations system (SRcS) using a GA adaptation with innovative PWA. With the GA advantages, SRcS helps users seek out and purchase a smartphone according to specification preferences, needs, and allocated budget. Tacitly, it helps to ease the time-consuming manual survey and comparison via websites. The outcome performed from the functionality testing by assessing and testing the use case function proves the SRcS functions work correctly. The usability testing using the five scale in UEQ shows a good result with a positive evaluation value mean scores that indicate the majority of the respondents preferred using the SRcS. The benchmark result also shows an excellent trend and prove the acceptance of SRcS. For the next improvement, SRcS can expand the fitness of the brand's choices, view the smartphone's picture in a 3D rotation image, and recommends the authorized seller.

ACKNOWLEDGMENT

The authors would like to acknowledge the Indonesian Ministry of Research and Technology and Universitas Pendidikan Indonesia for funding this work.

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