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An intelligent recommender system for low-cost product suggestions using vector space modeling

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ABSTRACT

Modernization in retail stores has improved in many ways to accelerate checkout process. Several businesses use self-service technology (SST) to provide convenient shopping experience for checkout and payment without having to interact with cashier. However, recommending similar products with cheaper price for tracking expenses using SST remains an unresolved issue. Customers face challenges to find cheaper products because of variations in brands and prices at retailers. This leads to wasted time and effort. This study aimed to determine a useful way to recommend cheaper identical products at self-checkout applications to improve consumer satisfaction without storekeepers. A vector space model is utilized in development of content-filtering approach. The utilization of product description keywords in vector space model is employed to suggest similar items, while selection rules are implemented to identify less expensive options. A self-checkout mobile application for supermarkets has been developed, which incorporates a content-based recommender system using term frequency-inverse document frequency (TF-IDF) and cosine similarity on product descriptions to suggest cost-effective alternatives without requiring user history. The application integrates intelligent product recommendation, budget monitoring, and mobile checkout into single platform. A preliminary evaluation study found that 95% of respondents had reported the application is useful in recommending cheaper items and 93% of respondents satisfied with its integrated features, confirming the potential of intelligent recommendations for autonomous shopping experiences. Future versions of shopping cart can include motion detector that automatically recognizes products without barcode scanning.

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1. INTRODUCTION

The prevalence of modern technology in retail industries has led to the innovation of mobile applications in stores to create a smart shopping experience [1], [2] for example, self-service checkout mobile applications that allow customers to check out easily without having to interact with frontline employees. This self-service technology (SST) not only provides customers with a new shopping experience but also can reduce the operational cost for retailers. SST has been implemented widely in various sectors, including supermarkets [3], [4].

Supermarket checkout mobile application is one type of self-service innovation that has been implemented in the mobile application that helps customers to check out easily without the engagement of storekeepers and having to wait in a long queue [5]. The supermarket checkout application allows customers to scan the barcode of the item using their mobile devices and add the item in the virtual cart. Then, the mobile application generates a QR code for the checkout process. This can accelerate the checkout process and minimize waiting times for customers.

The development of self-checkout mobile applications for retail industries offered customers smart shopping experiences [6]. The applications not only provide customers with flexibility to complete their purchase without wasting time at payment terminals but also should be able to provide enriched information to ensure shopping productivity [7]–[10]. For example, budget trackers and recommenders to keep track of customers' expenses and to recommend similar product at cheaper prices to support customers to make rational purchasing decision.

Budgeting when shopping at the supermarket is a complicated task because customers cannot effectively track their expenses. Further, customers tend to over budget when shopping without a tracker. One of the key factors in making budget work is tracking expenses [10]–[13]. In addition to that, finding cheaper products is a challenge for customers to stay on budget because products in supermarkets vary in brand and price. The buyer needs to be a smart buyer and to shop wisely by comparing prices of the item [14]. Customers who are on a budget must compare the prices of the products in the supermarket to find the cheapest price. This can be a challenge for customers because comparing prices of products in supermarkets can use a lot of time and effort.

This research presents an innovative method for improving customer experience at supermarket checkouts by incorporating SST, a mobile application, a recommendation system, and a budget tracker. The resulting system is referred to as SCABTRE. This study highlights the design and development of SCABTRE, a system capable of recommending alternative products at reduced costs and tracking expenditures in alignment with a specified budget. A vector space model is employed as a content-filtering method to recommend things to customers based on their similarity scores to previously chosen items. A budget overage notifier has been created to assist in expense monitoring by issuing alerts when expenditures exceed the established budget. A preliminary evaluation of SCABTRE's usability was conducted using a sample of 30 participants. This study's contributions include the development of a vector space model that integrates term frequency (TF) and inverse document frequency (IDF) with a cosine similarity technique.

2. RELATED WORK

SST is a digital interface that allows technology-based interactions with customers without employee engagement [13]. Prior studies have reported the improvement of SST for retail stores, especially in the supermarket, which has led to the growth of self-service checkout terminals [15]. This innovation became popular for retailers to reduce the waiting time for the checkout process in supermarkets as well as employee costs [14]. Although many retailers practice SST to enhance their service quality and customer satisfaction and to reduce operating costs, few studies have reported customers' negative experiences with SST, including the closure of terminals at certain times and the terminals' slow processing during checkout [15].

Many recent studies have shown the rapid growth in the use of smartphone applications for self-service checkout in retail stores, particularly supermarkets [5], [15], [16]. The use of smartphone applications for self-service checkout has changed the way that customers interact with retailers, such as to purchase products and the payment process. Such applications lessen the time at the self-checkout machine because the customer does not need to scan each item using the external terminal provided [17]. This results in significant cost savings not only by reducing customers' waiting time but also by excluding the need to buy self-service checkout terminals.

Data from several studies has suggested that customers are eager to have more information to make their own decisions about which products to buy, particularly at the cheapest price and with good quality [18], [19]. Hence, to improve satisfaction and innovative shopping experiences that are tailored to customers' needs, the smartphone checkout application should have essential features such as recommending similar products that have a cheaper price and tracking budgets. Such innovation features will provide customers with time, control and faster responses and improve supermarket operations for retailers in terms of efficiency, cost and interaction with customers [20], [21].

Given the improvement of machine-learning technology, current content-based recommender methods can build profiles for products. The content-based recommender method can compare the profiles of products and then recommend the most similar product that has a cheaper price. Several studies have used content-based recommender techniques to recommend similar products according to that customers' activity by using keywords that are assigned to the product in a database [22]–[24]. The content-based recommender

learns from individuals' user preferences to make recommendations according to the features of the product's content and not by considering other users' preferences [25], [26]. Content-based recommender techniques, such as naïve Bayes classifier, cluster analysis, decision tree, and vector space model, are able to learn from individuals' user preferences to make a recommendation.

The advancement of recommender systems has substantially beyond basic content-based and collaborative filtering methods. Transformer-based models, pre-trained on extensive text corpora, demonstrated exceptional efficacy in comprehending semantic product descriptions and user reviews, facilitating a profound understanding of product attributes and user intent beyond mere keyword matching [27]. Moreover, session-based recommendation methods, which analyze a user's sequential activities within a single shopping session without necessitating extensive personal information, are especially pertinent for anonymous or first-time users in a self-checkout environment [28]–[31]. The consolidation of multimodal data incorporating text, photos, and shelf-location information represents an expanding boundary, enabling algorithms to comprehend product similarities from many viewpoints [32]. Reinforcement learning frameworks are being investigated in the realm of cost-saving recommendations to optimize complicated, multi-objective user goals that reconcile price, quality, and brand preference in real-time [33]–[35]. This study utilizes a recognized TF-IDF and cosine similarity methodology for its clarity and effectiveness with product descriptions, positioned within the wider context of intelligent systems. The proposed application fills a significant void by implementing core principles of content-based filtering to provide autonomous, real-time decision support at self-checkout, a domain where intricate personalized models frequently encounter data sparsity and latency issues.

3. METHOD

3.1. Methodology

A hybrid methodology as shown in Figure 1 that integrates both waterfall and agile methods was employed in this study. The hybrid methodology paradigm comprises five distinct phases: requirement, design, develop, test, and evaluation. The requirements and evaluation phases adhere to the waterfall technique, whereas the design, test, and build phases align with the agile methodology.

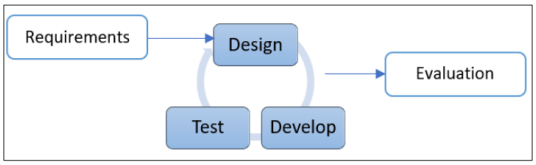


Figure 1. Hybrid methodology

During the requirement phase, the essential project resources were collected, encompassing data, tools, and recommender approaches. The gathered data comprises the barcode, description, and price of the product. During the design phase, the study produced the high-level system designs, flowcharts, and graphical user interfaces. Throughout the development period, the study employed Android studio as the principal platform for constructing mobile application. The mobile application development included the integration of a budget tracker and recommender system that utilizes a content-based filtering technique. The mobile application's performance was assessed by implementing 10 test cases that focused on its functionality. The usability of the mobile application was evaluated through the utilization of a usability questionnaire, which measures characteristics such as usefulness, ease of use, and satisfaction.

3.2. Proposed architecture

A supermarket checkout mobile application is proposed, which allows customers to purchase products in a supermarket at a cheaper price using the recommender feature and to be able to keep track of current expenses with the target budget. Figure 2 shows the structure and components in the SCABTRE application architecture. There are four components including: recommender, virtual cart, budget tracker, and user input.

This study employs a content-based filtering strategy, utilizing a vector space model constructed with TF-IDF and cosine similarity. The vector space model is a computational method designed to assess information similarity through various keywords, hence simplifying the complexity of the relationships among those keywords. TF-IDF is a weighting mechanism employed in vector space models that utilizes

cosine similarity to determine similarity [32]. Cosine similarity computes the distance between the document vector and the query vector to assess their similarity. In (1) illustrates the application of a variable's value associated with a word indicating relevance according to the TF-IDF weighting algorithm [36]. The value is referred to as the tf * idf weight (term frequency multiplied by inverse document frequency). The tf * idf weight, $w(t,d)$, of term t in document d is determined by the term frequency in the document ($tf_{t,d}$), the document frequency of the term (dft), and the total number of documents in the collection (N).

$$w(t,d) = \frac{tf_{t,d} \log\left(\frac{N}{df_t}\right)}{\sqrt{\sum_i \left(tf_{t_i,d}\right)^2 \log\left(\frac{N}{df_{t_i}}\right)^2}} \quad (1)$$

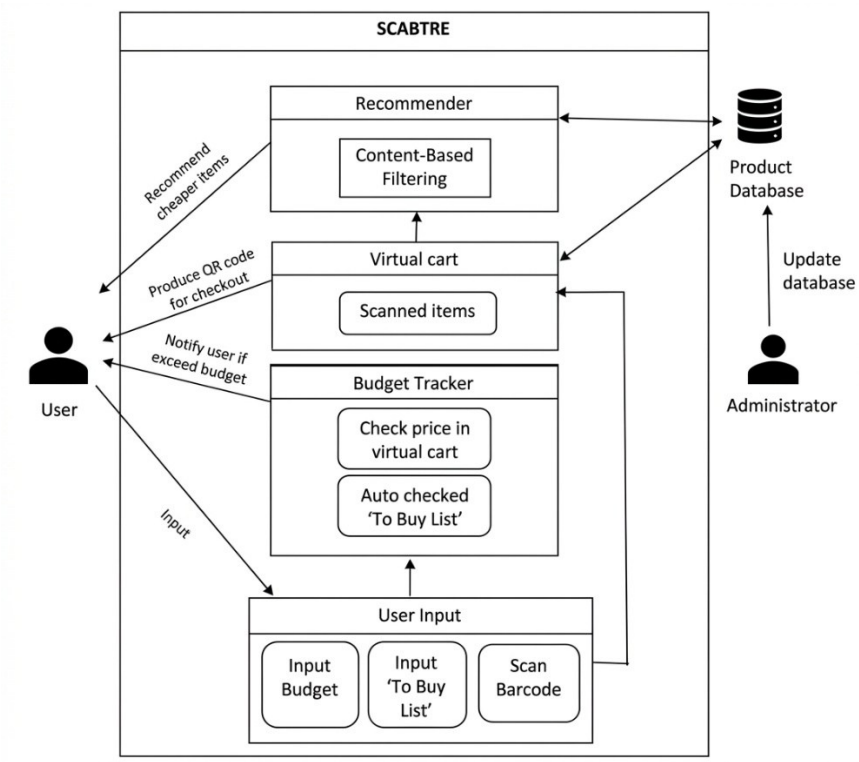


Figure 2. Self-checkout and recommender application architecture

In this study, the TF-IDF weighting algorithm uses the keyword of the product and finds similar items from the product database to recommend similar items. The weighting is often used for scoring and ranking a product's relevance. Then, it sorts the product list according to the similarity score and sets a threshold value of 0.2. This means that the item that is recommended needs to have at least a 20% similarity score. After that, the application implements the selection rules on the similar items to find cheaper items. Algorithm 1 shows the TF-IDF algorithm implemented in SCABTRE.

Algorithm 1. TF-IDF algorithm - convert text to vector
1. Loop for word sequence text
2. Declare tmp_wd
3. Check tmp_wd length > 0
4. Check word frequency vector contain tmp_wd
5. True
6. Declare freq1 freq2
7. Assign freq1 and freq2 with values from word frequency vector using tmp_wd
8. False
9. Read values and create object vals

10. Find word frequency vector with vals
11. Add distinct words tmp_wd
12. End
13. Close

TF-IDF generates the frequency score by using the frequency of the term in the products' description. This score is used in the cosine similarity algorithm to calculate the similarity score between the selected product and other products in the database. Algorithm 2 shows the cosine similarity algorithm in SCABTRE.

Algorithm 2. Cosine similarity algorithm
1. Initialise VectAB, VectA_Sq, VectA_Sq
2. For each distinct word
3. Read values and create object vals12 from word frequency vector
4. Initialise freq1 freq2
5. freq1 = vals12 from val1
6. freq2 = vals12 from val2
7. Assign VectAB with accumulative value of vectorAB and multiplication of freq1 and freq2
8. Assign vectorASq with accumulative value of vectorASq and multiplication of freq1 and freq2
9. Assign vectorBSq with accumulative value of vectorBSq and multiplication of freq1 and freq2
10. End for
11. Cosine similarityScore = VectAB/ Math.sqrt(vectorASq) * Math.sqrt(vectorBSq)

The cosine similarity algorithm computes the similarity score based on the score produced by the TF-IDF method. It generates a similarity score for each product in the database. The products are arranged in descending order based on the similarity scores produced by the cosine similarity algorithm. Algorithm 3 illustrates the sorting algorithm. This study use the selection sort algorithm to arrange the products based on the similarity scores generated by the cosine similarity technique. The sorted product list must be filtered to identify only the less expensive goods. The selection criteria are employed to refine the list based on the pricing of the chosen product.

Algorithm 3. Sorting algorithm
1. For each product do
2. Assign min with i
   For j=i +1 to n do
   If A[j] less than A[min] then
   Min =j
   End if
3. End for
4. Swap temp = mark[i] and A[i]
5. End for

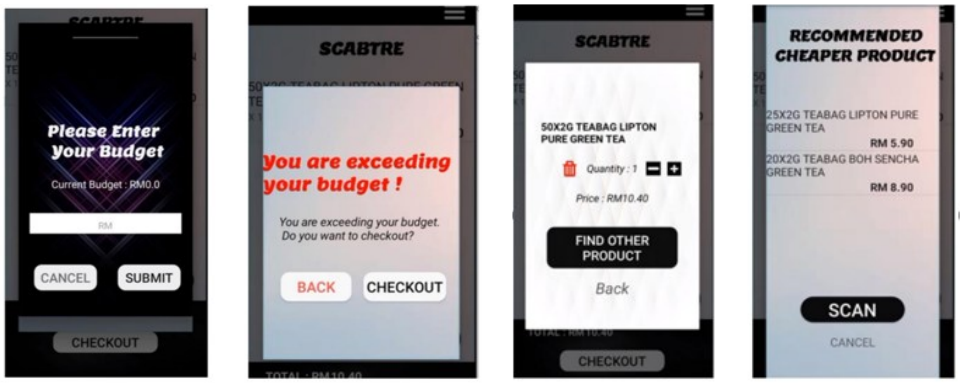
Algorithm 4 shows the selection rules that are used to find the cheaper item by using a looping technique. The looping technique is used to filter each product according to its price. The list of products that is filtered using the selection rules needs to be filtered according to the threshold value. The reason for filtering the products is to find suitable products that meet the minimum similarity score according to the threshold value. The threshold value for the recommender system is set to 0.2. This shows that the products need to have at least a 20% similarity score with the selected product. The algorithm checks the similarity score that is produced by the cosine similarity algorithm. The products that meet the minimum 0.2 similarity score are added into an array list called cheaper list. The list is the recommended cheaper products that are displayed on the output.

Algorithm 4. Selection rules algorithm
1. For each product do
2. Check price for each product
3. True
   Check price > threshold value
   True
   Create recommendedProduct as objects
   Add to cheaper list
   Display the cheaper list

End
4. End
5. End for

3.3. Mobile application development

A prototype of a self-checkout and recommender application, named SCABTRE, is developed in this study to implement the content-based filtering approach for recommending cheaper products. Figure 3 presents the user interfaces of SCABTRE. Figure 3(a) shows the insert budget page, Figure 3(b) shows the budget notification, Figure 3(c) shows the item page, and Figure 3(d) shows the recommender page. The prototype has three main functions: i) barcode scanner, ii) budget tracker and iii) recommender. SCABTRE uses a mobile camera to scan the barcode of the product. Then, SCABTRE searches for the scanned product in the database using a sequential search algorithm to find the product and add it to the virtual cart. SCABTRE is able to track users' expenses and to send a notification alert for spending over the target budget. SCABTRE is able to recommend similar products that have a cheaper price using the recommender feature.



(a) (b) (c) (d)

Figure 3. SCABTRE user interfaces: (a) insert budget page, (b) budget notification, (c) item page, and (d) recommender page

3.4. Evaluation

Thi study conducted a preliminary user evaluation to evaluate the usability of SCABTRE and the functionality testing to test the functionality of SCABTRE. The functionality testing was performed using five test cases. The test cases were designed comprises of input validation, user interface interactions, and data processing as shown in Table 1. The preliminary user evaluation required participants completing online usability questionnaire that consists of 10 questions. The questionnaire aims to measure three elements of usability, which are usefulness, ease of use and satisfaction. Before participants started performing the evaluation, they were asked to follow the instructions written on the questionnaire.

Table 1. SCABTRE test cases

Test cases #	Test scenario	Expected outcome
T001	The user input the amount of budget	Notify the user if the user has exceeded the budget at the checkout process
T002	The user scans the barcode of the product	The product will be added into the virtual cart
T003	The user adds "To buy list" product into the virtual cart	The system will automatically check the checkbox of the correct item
T004	The user clicks "Find other product" button	The system will list the recommended cheaper item
T005	The user clicks "Checkout" button	The application generates the QR code for the checkout.

4. RESULTS AND DISCUSSION

The preliminary user evaluation was performed by thirty (30) voluntary participants, which consists of 19 female and 11 male. Out of 30 respondents, 26 respondents are in the range of 18 to 25 years

old. Two respondents are in the range of 40 to 50 years old, and the remaining respondents are in the range of 26 to 30 years old.

The results of functionality testing have indicated that the SCABTRE functions as intended in every test scenario. All functionality that has been tested have passed, meaning that the system functions as expected in all scenarios. The responses of usability evaluation are shown in Figure 4 are highly positive. Most participants responded that they agreed or strongly agreed that the SCABTRE application was perceived to be highly useful, easy to use and highly satisfying in terms of usability.

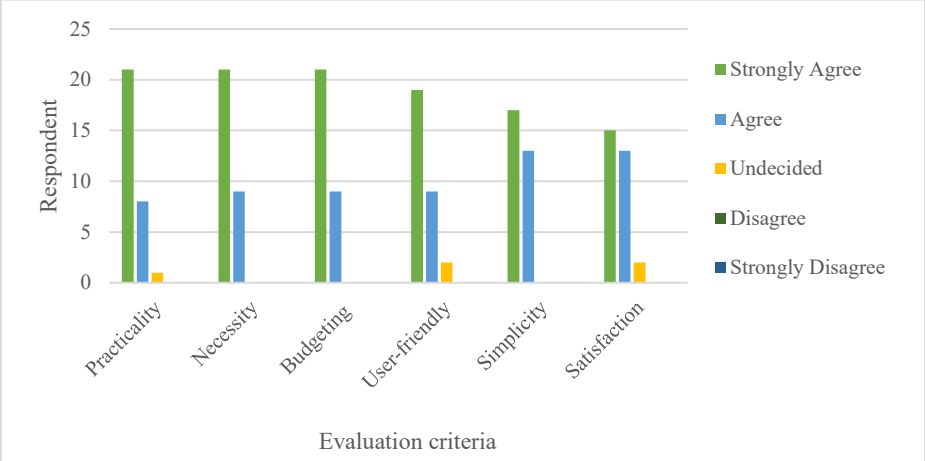


Figure 4. Responses from user evaluation

All participants agreed the recommender application accelerates supermarket checkout and 95% strongly agreed it met their needs in recommending cheaper items and budgeting. This indicates that the system helps to accelerate the checkout process in the supermarket and to manage user budgets. In terms of simplicity, all participants agreed that the application is easy to use, 93% agreed it was user-friendly, and a majority noted consistent system performance. Furthermore, all participants were satisfied and would recommend the SCABTRE to friends, while 93% of participants admitted that they need the application in their daily lives because it can reduce wait times and assist with grocery budget management.

These findings validate using a vector space model (TF-IDF and cosine similarity) for automated product recommendation in supermarket self-checkout applications. TF-IDF algorithm generates the frequency score from product's description, which cosine similarity algorithm then use to rank alternative products by semantic similarity in descending order. This indicates the application's capability to assist users in making budget-conscious decisions using machine learning techniques.

In comparison with existing relevant studies, which often depend on collaborative filtering or hybrid techniques that require user history records [22]–[24], [37], this study use content-based filtering technique operates on product description. This application appropriate for cold-start situations or users lacking historical preferences. Furthermore, while previous research focused on specific functionalities of SST such as fast checkout or queue minimization [38], this application integrates recommendation, budget monitoring and mobile checkout through one platform, providing a holistic approach. This application provide significant advantage in terms of computational efficiency by facilitating local processing within a mobile application. However, constraints exists from a fixed similarity threshold (0,2), which may not be applicable across all product categories. It is intriguing that the budget monitoring feature received equal amounts of positive feedback, despite the fact that the primary objective was to recommend the feature. This indicates that users have a preference for financial control features.

5. CONCLUSION

This study demonstrates the significance of integrated, decision-supportive aspects in evolving SST from a basic transactional instrument into an intelligent shopping assistant. The creation of the SCABTRE application demonstrates that a content-filtering strategy, even in the absence of user history, may proficiently meet a fundamental customer requirement—recognizing economical alternatives—within the realm of autonomous shopping. The favorable initial assessment indicates that user satisfaction with SST is

substantially improved not only through process automation but also by providing consumers with real-time, actionable financial and product information. This work primarily contributes by illustrating a paradigm shift in retail technology design, in which value is generated through the integration of artificial intelligence to facilitate real-time consumer decision-making, thereby directly associating technological functionality with benefits for customers. Regardless positive findings, this study also establishes opportunities for additional improvement. Future endeavors must tackle scaling issues, dynamic pricing, and contextual personalization. Innovative artificial intelligence methodologies, like deep learning embeddings and hybrid filtering techniques, may be investigated to enhance recommendation precision and adaptability. Overall, this study contributes an innovative and practical artificial intelligence use in retail, significantly advancing intelligent, customer-focused self-service technologies.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration

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Norzilah Musa		✓		✓	✓	✓				✓			✓	
Waleed A. Hammood		✓		✓	✓	✓				✓				
Marshima Mohd Rosli		✓		✓	✓	✓				✓			✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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