



FAKULTÄT FÜR INFORMATIK

TECHNISCHE UNIVERSITÄT MÜNCHEN

Master's Thesis in Informatics

**Implementation and Evaluation of a
Healthy Food Recommendation System for
Mobile**

Muhammad Kabir Khan





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Implementation and Evaluation of a Healthy Food Recommendation System for Mobile

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Acknowledgments

Abstract

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1 Introduction

The motivation behind this Master Thesis is to implement and evaluate a Healthy Food Recommendation System for Mobile. In the beginning, it provides overview and give the reasoning about the selection of system. Relevant background and related work is presented, Followed by the development and design process together with the evaluation process will be presented.

This chapter will enlighten the motivation behind developed system in Section 1.1. Followed by goals in Section 1.2. Whereas Section 1.3 will provide a brief outline on structure of thesis.

1.1 Motivation

Rapid innovation and significant advancement in the field of technology and scientific research has made smartphone a primary computing and communication device. Smartphone is now become a necessity of life and people use it as an assistant for their day to day work. According to latest survey more than half of Internet traffic is accounted by mobile device. Enhancement in communication technology and flexible data option provided by network operators has increase relevance of interactive mobile applications. Packed with hundreds of features smartphone use different applications for variety of functionalities which required internet connectivity. Furthermore, smartphone support touch screen and rich support of multimedia and other application take the user experience to the next level.

Suggestions are the important factor of our day-to-day life. From watching a movie, to cooking and to on shopping. We need valuable advice. Recommendations are always helpful in choosing a better alternative. It not only save time but also minimize the individual's effort.

Recommender system are increasingly popular now are days. Form e-comers to movie websites, they not only help to increase business but also behave an personalize user preference assistance. Another aspect of describing Recommend system is filtering technology that user to filter suggests the information to user according to his taste. In order words we can also say that Recommender systems are the smart search engine,

which suggest result by, compare different items with each other. Research and advancement are going on this domain in order to improve the quality of recommendations. The most important goal for recommendation system designers is user willingness to peruse recommendation provided by the system. Fundamental process of recommendation is finding and conceptualizing relationship of item, current context and how the message is communicated, opens up the way of persuasiveness in recommendations.

Services provided by recommendation system through e-commerce to cooking are numerous in nature. Searching of products returns an overwhelming set of options. For instance, Comparing and Filtering of products among irrelevant set and find the suitable product. Such techniques work fine with web interface, whereas, smartphones they are not very useful due to hardware limitations. Critique-based recommendation helps in revision and acquisition of user preference, in order to improve quality of recommendations.

One the basic need is Food among human. Good health represents proper dietary habit. However, diet plan is always based on person's physical conditions like gender, weight, age and health status. Furthermore, taste and food preference is differ among individuals. Therefore, creating balance dietary plan based on individuals taste and health preference is always challenging.

The World Health Organization [29] is predicting that the number of obese adults worldwide will reach 2.3 billion by 2015 and the issue is attracting increased attention. Therefore, electronic food management systems have become a hot topic and, are under consideration to replace traditional paper based program. Idea of using electronic devices for health related matter is not new; similar devices are in use by patients for medical reasons e.g. Glucometer, and blood pressure monitor. People want, to carry better life style and to live healthy. Therefore popularity of food monitoring systems is getting popular. These systems are not only providing valuable services but hold user preferences and keeps history to provide more personalize recommendations. Recommendations are based on food ratings and browsing histories.

Food recommendations have gotten a tremendous amount of success and still in research phase for further improvement. Along with significant advancement and feature set like similar recipes, recipe nutrition detail, where to buy ingredients from some research, some wholes are still remaining. Indeed recommendation techniques like collaborative, content and knowledge based filtering are good for job done. But food domain is not quite simple. User preference and taste not only change by their mood but much more depend upon their health. Therefore, Active learning and critiquing

techniques are required to improve better recommendation. So that user can give their feed back and get what ever his preferences are. Mostly approaches are done critiquing by using rating of recipes and generate their result by using celebrative or content based filtering. Similarly, knowledge based filter digs some more; here rating is based on ingredients. Furthermore, persuasion of recommendation is always not guaranteed in all cases. Clearly the system is not able to provide the best recommendations due to its detachment from the current situation; what is lacking in these approaches are intersection of persuasiveness, active learning and critiquing and last but not the least user preference context.

This work focuses on generation of health food recommendation on a mobile platform. Recommendation relies on user context, which allow user to critique, based on ingredients and recipes depends on his health and taste through which system will perform active learning. Lastly all recommendations should be persuasive in nature. in order to achieve persuasiveness in recommendations, we focus on user interface and the explanation of recommendation. Which helps user to get an idea why system generates this recommendation to me.

The following short description of the target scenario will illustrate the driving idea behind this research project.

John is a software engineer and very health conscious. He has a tight schedule due to work and gym but loves to cook. He wants to keep track of his diet depends on his taste and preferences. Furthermore, he wants try out some new food base on his time schedule

1.2 Goals

On the basis of scenario, describes in last section, this work reflects the goals which are stated below:

A recommendation is valuable if it interests the user. To determine the generated recommendation is according to user interest entails to our first primary goal, which is offering Persuasive recommendations. Major factors should be considered before given suggestion is Message and Source. Therefore our Second goal is to implement Active Learning and Critiquing approach to justify our suggestion. Since Critiquing relies on context that's why it is important to understand the Consumption and Accessibility context which infers our third goals. Similarly understanding the food ontology refers

in scenario helps us to understand forth goal of system. Finally how the user will interact with his device conveys our last goals, which is Mobile user interface.

To achieve primary goals there are several other interesting secondary goals, which facilitate, how our primary goals should be achieved. Starting with the research phase, which includes question and answers to user how they want to use such system in order to achieve better usability. Next focus on existing search work how the other system implements food recommendation scenarios, finding out what are their weakness and strengths. Food ontologies understanding how they are interrelate with other. What factor in which recipes are dependent on in order to develop strong system. Understanding user context which time he prefers which recipe. Furthermore, it is important to research on what researches and related work are out there under Persuasive and Active learning and Critiquing system to grab the understanding, how we can get inspiration from their valuable approaches and work. Finally focus on user experience of such application is one of challenging task, how and where to show the important aspects of recipe in our interface, so that it is easy to learn and has improved usability in comparison with current market applications.

Once the research phase has done next step to collect the functional and non-functional requirement of the system, which is collected by interviewing friends and family volunteers. Once the system is build it has been tested with gathered functional and non-functional requirement and find out the limitation or boundary conditions of system. More over iOS client needs to be test with given requirement additionally user satisfaction should be required for usability test.

Finally, evaluation of developed prototype by user study. In order to clarified the methodologies and processes followed by our selected approaches. After finishing the evaluation reflected results leads to potential improvements and opens up the new direction of research.

1.3 Outline

Division of this thesis is split up into six chapters. *Chapter1* contains introduced the ideas, motivations and goals.

Chapter2 starts with background in which some definitions and classification of recommendation systems, Followed by different types of profiling and contexts that impact on recommendations. Furthermore, in related work section, pervious work of

Persuasiveness, Critiquing and Personalized food recommendation techniques have been discussed.

Chapter3 explains the Profiling and Context in details along with factors of recommendations. Moreover it covers algorithms that are used to develop the system.

Chapter4 discuss the System design and architecture phase, which hold the all ERD, components view, servers on which system depend. In the end of the chapter API calls are mentioned which are provided by server.

Chapter5 elaborates how the user study has been conducted by mentioning the goals, methods, and testing framework along with the dataset. In the end of this chapter measured results and discussion is mention.

Chapter6 will summarizes the achievements and gives clues about further development and research.

2 Background and Related Work

This chapter will establish the foundation of Persuasive recommendation system along with active learning and critiquing approach. Prior to in depth analysis, it will provide important background information along with some required definitions. Additionally, related work will presented, as the chapter proceed further to the end..

2.1 Definitions

2.1.1 Recommender System

Recommender Systems (RS) are search tools, which supports user decision-making by providing the suggestion that, are according to their interests. Such systems are widely uses from social networking through e-commerce sites in order to achieve different purposed. In e-commerce site, they help not only to serve the customer by suggesting items according to their preferences but also support business to improve in its sale. On the other hand in social network site, to suggest friends or pages like according to user preferences. According to Ricci [Ricci, 2010] "RS are information search tools that have been recently proposed to cope with the "information overload" problem, i.e., the typical state of a web user, of having too much information to make a decision". Proposed solution [Resnick and Varian, 1997] is an intelligent system that suggests the product or service that fulfill the user's preference in given context or situation. Suggestions provided by such systems are depended on the model how they are keeping information. Majority of RS are typically community based. In this kind of modeling suggestions are depend about item popularity among the user. Where popularity is calculated by ratings. Important question that arise in such systems are to find item accuracy according user preferences. On the other hand Personalized models are used that depends on the various factors which includes user's preferences, history of bought/liked items, or the items the user has ranked in the past. Various techniques are use in the developing of recommender system. Classification of recommendation systems [Ricci, 2001] will be discussed as follows.

Content-based filtering

In this technique recommendations are based on user preference. System recommend items that similar to one is liked by user. Item similarity is calculated by features associated with the compared items [Ricci , 2001]. For example, if a user has rated positively recipe A under the category of sweet then next suggestion that is provided by the system is one which is similar to one user has like before.

Collaborative-based

Collaborative filtering is technique in which system find the correlation between item and user based opinions of other users which having a similar taste in past [Shapira , 2001]. Initially system calculates all similar taste users for the current user and calculate the recommended item that contains either rated or liked by other users having similar taste. Importantly in this approach item speciation will not be considered. For instance, if user like recipe A then next recommendation would be recipe that there are other users who liked recipe A also liked recipe B.

Demographic

Recommendations are generated according to user demographic profile. Recommendations can be produced for different demographic niches by combining the ratings of users in demographic clusters [Mahmood, 2007]. For example, suggestion provided by the systems are shown according to user's age.

Knowledge-based

In knowledge-based systems item recommendation is based on domain specific knowledge, which justifies how certain item features meet according to user's preferences [Ricci , 2001]. Importantly, it uses predication techniques namely Case-based reasoning which reuses the cases past cases that are similar to current case in order to identify item set of recommendation.

Community-based

Type of recommendations provided by this kind of system based on preference of user friends. According to Ricci research [Ricci, 2001], People tend to rely more on recommendations provided by friends rather than on recommendations from anonymous individual having similar taste. Such type of RS model relies on user's social relations including preference of user's friends. Suggestions depend on rating that is provided by user's friends.

Hybrid Recommender Systems

Hybrid system is a fusion of any two or more techniques motioned above. Ricci [Ricci , 2001] explains the motivation behind such system to avoid the limitation of one technique. For instance, Collaborative filtering have cold startup problem i.e. they are unable to suggest those items, which have no ratings. On the other hand Content-based doesn't have such limitation by combination of both approach new hybrid system can be formed. Similarly, Burke [Burke, 2007] proposed the combination techniques to create a new hybrid system.

2.1.2 Contexts

Recommendation techniques used by traditional system relies on vector of item rating and user preferences. According to Suchman [23] these approaches ignores the notion of "situated actions", which infers that user have particular context and item preference within one context may be different for another context[1]. Absence of context may lose information predictive power because of aggregation of multiple contexts. For instance, User wants to buy cloths of his child gives results according to his dressing choice due to contextual information missing.

Since context is a multi dimension topic therefore vast amount of research has been done in area, narrowing down role of context in recommender system, context can be defined as all information according to given situation. One of the early definitions of context in terms of operation [20] defined as where you are, who you are with, and what resources are nearby. As reach goes by new and most sited definition of context according to Adomavicius [1] "Any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves". Futhermore, [5] while observing the uses of context he classified into to two views namely *representation* and *interaction* views. He assumed four key assumptions for describing representational view. context is independent from underlying activity, delineable, stable and in a form of information. According to this view, context can be known prior as it is a set of observable attributes and structure of these attributes does not change with respect to time. Futhermore, [5] while observing the uses of context he classify into to two views namely *representation* and *interaction* views. He assumes four key assumptions for describing representational view context is independent from underlying activity, delineable, stable and in a form of information. According to this view, context can be known prior as it is a set of observable attributes and structure of these attributes does not change with respect to time. On the other

hand interactional view features are dynamic. It assumes that context and activity have a relationship.

Adomavicius [1] put forward research [5] on categories and explains recommender system can have different types of knowledge, which may include the exact list of all the relevant factors, their structure, and their values, about the contextual factors. He classifies the knowledge of a recommender system about the contextual factors into three categories;

Fully observable refers to explicit knowledge of structure and values of contextual factors of application at the time when recommendation are made. Theses factors refer as Purchasing Purpose, Shopping Companion and time. For example, User wants to buy shirt, besides having information of selling point and item. Theses may include information about the time, for whom. *Partially observable* application has some of information about the context explicitly. For instances, Purchasing Purpose, Shopping Companion and time all information given but the structure is missing. *Unobservable* no information regarding contextual information is provided explicitly. Utilizing only the latent knowledge of context in an implicit manner makes recommendations. For example, the recommender system may build a latent predictive model, such as hierarchical linear or hidden Markov models, to estimate unknown ratings, where unobservable context is modeled using latent variables.

Furthermore, Adomavicius [1] find out the dependency of contextual factors over time and classify them into categories. *Static* The relevant contextual factors and their structure remains the same (stable) over time. *Dynamic* contextual factors change in some way.

How Contextual Factors Change	Knowledge of the RS about the Contextual Factors		
	Fully Observable	Partially Observable	Unobservable
Static	Everything Known about Context	Partial and Static Context Knowledge	Latent Knowledge of Context
Dynamic	Context Relevance Is Dynamic	Partial and Dynamic Context Knowledge	Nothing Is Known about Context

Figure 2.1: Contextual Information Dimensions.

[1]

Representing and Modeling Context

Classical the recommendation system has the prediction problem in which user's rating for item reflects the degree of user preferences. Therefore, a recommender system tries to estimate a rating function.

$$R : Users \times Items \rightarrow Ratings \quad (2.1)$$

It's a 2D matrix of user-item to an ordered set of rating values. Where R a general-purpose utility (or preference). Since the value of R is partial function therefore rating of all user-item are not known which arise the predication problem.

$$R : Users \times Items \times Contexts \rightarrow Ratings \quad (2.2)$$

In contrast, context aware recommend have additional evidence to estimate user preference on unseen item. Contextual evidence can be applies to input function and viewed as "multidimensional". Where, any information related to data and user can be refer as Contextual information

Paradigms for Using Contextual Information

According on algorithm approaches of context aware recommendation, represents in form of $U \times I \times C \times R$, Where U is for User, R denotes rating, C is contextual dimension, and produce contextual recommendations list $i_1, i_2, i_3 \dots$ for each user u . Figure 2.2 illustrates the Paradigms used in processing Contextual Information. These are categories as follows:

Contextual prefiltering In this filtering Context is applied an input. With the help of any classical 2D recommendation data selection approach, applies current context which is used for selection of relevant ratings and dataset.

Contextual postfiltering Prediction of rating is applied with the help of traditional 2D recommender system technique. On the resultant set of recommendation applies the context for each user.

Contextual modeling directly integrates the contextual information in the modeling technique as part of the rating estimation. .



Figure 2.2: Paradigms for Incorporating Context in Recommender Systems.
[1]

2.1.3 User Profiling

User profiling is process of acquiring information about the user, which helps in constructing the user model. Rate of acceptance and effectiveness of recommendation will effect how much system has information about the user. Tang [25] explains as In the context of software applications, a user profile or user model comprehends essential information about the user. It also refers and digital representation of person in a system and hold the person's preferences. Variations in user profile content depend on application. Some applications depend on demographic information of user while other relies on rating, liking, disliking or other preferences. Also, consideration of user interaction and behavior take plays an important role for providing precise recommendations.

Schiaffino [19] stated that discovery of differences and similarities in interests among users is a key to provide personalized recommendations Which implies that application users have different preferences and interests to achieve their goals which leads to importance of creation of user profile in order to find out relationship between user

according to their interests. Content of user profile depends on application domain and variations are presents application. Categorically there are two methods to gather content of user profile. First method is manually, in this technique users are being interviewed, fill the some form or questionnaires. For instance asking about his demographic profile like where he is form, which dishes he likes or rating based questions like how frequently he eats junk food? On the other hand by mean of implicit learning about user preference which requires artificial intelligence (AI) techniques like Case-based reasoning, Bayesian Networks, Artificial neural networks. Most of these techniques are beyond the scope of this work so they will not be described in more details. Fundamentally there are two different alternatives to build a user profile; either the information is obtained explicitly from user or implicitly through the observation of user's actions. The next section describes these alternatives.

Explicit Profiling

Explicit profiling often known as explicit user feedback is the simplest way of gathering information about users. In this technique, user has to fill questioners in order to develop profiles. Profiles developed by this techniques are totally depends on the questioner. Normally, data contains demographic information regarding the user like name, age, location and other preferences. Gauch [19] suggests input methods that allows user to rate item according to their interest. Alternatively system can provide check box and text field in order to get preference of user. *HTML forms, Questionnaires, Rating, User preference and Touch sensors* are some techniques user to obtain explicit profile. Where as, the limitation of this technique is that it requires user time and willingness to provide their data. Some user has reservation in regards to provide their personal information because of potential privacy concern. However user's preference can always be determine via this technique.

Implicit Profiling

Implicit profiling is also known, as implicit user feedback is another approach for building user profile. It is popular and widely used methodology to develop user profile based on user 's acquired information. Mostly profiles are derived form monitoring or observing user activities. Information acquires by the system helps them to ensure the given recommendation is according to user interest. For example popular website for watching video YouTube. It recommendation is made on similar to those video is watch by user in past. Single-sign-on (SSO) [hursti1997single] one the most

common methodology for user registration. Since the information is implicit they may contain user demographic information. Similarly user preference like, dislike, location can be fetched by integrated related third party services. Information obtained from this mechanism plays an important role in personalized recommendation system. TextitSearch logs, Browser cache and User monitoring agents are some techniques used to generate implicit profile. Main advantage of this technique user doesn't have to enter form and provide their information. Kelly [19] provides an overview of standard techniques that are helpful to build user profile and information types about the user that can be inferred from user's behavior.

2.1.4 Conversation-based Critiquing Recommenders

Recommender systems may also vary in the function to the extent that user can get engaged in the dialogues. In traditional techniques data was collected once and terminated after recommendation are made. Assumption of these approaches is user knows all his preferences at the beginning which was not the case. Whereas, user taste may change over time and he wants to interact with different options. Smyth [10] handles this problem and called "Conversational recommendation system" (CRS). He states that CRS have their origins in conversational case-based reasoning (CCBR) which apply similar techniques to elicit query information in problem solving domains and diagnostic tasks." It is an interactive approach in which user preferences are established through conversation session. At first initial set of recommendations are given to the user. System adapts the user feedback to further enhance the recommendations. Smyth [10] distributed feedback into three categories. *Rating-based* in this approach user provides rating for an specific item. *Critique-based* where user add constrain over item features. *Preference-based* in which user indicates its preference for one particular item over the others.

2.1.5 Active Learning

Active learning (AL) is a methodology to learn about user's preference by asking him/her to rate a number of items known as training point [18]. Data is formed by model that approximates user's preference. It is useful where user's preferences are change with respect to context. Rashid [16] explains that objective of AL may varies according to objectives of recommendation systems. For example, what is important in the recommender system being built? The difficulty of signing-up (user effort)? If the user is happy with the service (user satisfaction)? How well the system can predict

a user's preferences (accuracy)? Furthermore, this approach can solve cold startup problem in an effective manner. Figure 2.3 explains how interactive process works in order to obtain training data, unlike passive learning, where data is simply given to system in a linear fashion. Rubens [18] categorized AL method according to their primary goal.



Figure 2.3: Active vs Passive Learning
[18]

Instance-based Methods

In kind of approach points selection is relies on their properties in an attempt to predict user's rating by the closet match to other user, without have explicit knowledge about underlying model [2]. Whereas, it assumes that under consider model any data and rating predictions are accessible.

Model-based Methods

In this methodology point selection is based on best construct model that explains data supplied by the user to predict user ratings [2]. Similarly, select point are used to maximize the reduction of expected error of the model. Whereas, it assumes that in addition to any data available to instance-based methods, the model and its parameters are also available.

Modes of Active Learning: Batch and Sequential

Since the expectation of user is to high for the system while they are performing interaction. They expect immediate output from the system. One common approach is to recalculate the rating of item once user rated single item, known as sequential mode.

However another possibility is that to allow user to rate several features of items or rate several item before model readjustment known as batch mode. As immediate reflection of data in sequential mode is an advantage but cost of interaction will always effect. Therefore, trade-off exists between Batch and Sequential AL: the usefulness of the data vs. the number of interactions with the user.

2.1.6 Persuasive Recommendations

Traditionally, prevalent research in recommender systems has been focused on algorithms development and evaluation that provide precise recommendations[30].The presumption behind the algorithm that its accuracy contribute to the quality and acceptance of the recommender systems has been changed lately[13]. Context and profiling techniques are also emerged as an important pillars.Additional factors which are important and should be focus on is presentation of recommendation so that user can interact with the system in more continent fashion[13], transparency of system or explain working of system to the end user[22], persuasion[15] and recommendation's novelty[4]. Fogg [7] defines persuasion as *the attempt of changing people's attitudes or behaviors or both*.However, explanation of recommendation also have influence on user [12] [9].

Persuasion factors

Aristotle in Rhetoric [8] was the first one how talked about persuasion. Furthermore, he claims textit ethos/character of the speaker, *message's receiver pathos/emotions* and textit logos/argument are the main elements that plays an important role in persuasion. Since, difference of opinion exists in factor of recommendation. The mot cited one is Cialdini's [3] known as 6 Influence Principles (also known as Six Weapons of Influence) and if they implemented in a system then effect of persuasion increase. Theses principle include; textit Reciprocity (humans have the tendency to return favours), textit Commitment (or consistency: people's tendency to be consistent with their first opinion), textit Social proof (people tend to do what others do), textit Scarcity (people are inclined to consider more valuable whatever is scarce), textit Liking (people are influenced more by persons they like) and textit Authority (people have a sense of duty or obligation to people who are in positions of authority). Where Figure2.4 indicates effect of Communication Persuasion Paradigm[31].



Figure 2.4: Communication Persuasion Paradigm
[31]

Explanations in Recommender Systems

An explanation consider an additional information provided by system output to achieve certain goals [27]. Explanation persuade user to try or buy recommended item[28]. Several aspects should be considered in order to introduce explanation into the system. Following are the seven goals for explanation in recommendation system[26].

1. **Transparency** in recommendation system helps to understand how the recommendations are generated and how overall system mechanics[26]. Furthermore, it allow user to check the quality of system and in case anomalies user have an idea why system is given this result. Let consider an example, suppose system recommends a movie in comedy genre for a particular actor although user is not interest in it. System will provide an explanation you like some movies of this actor that's why it is in your recommendation.
2. **Scrutability** allow user to misguided assumptions made by system. Since user preferences may always change due to contextual factors. Therefore, it is important that explanations enable the user to understand what is going on in the system and let them exert control over the type of recommendations. Scrutability is related to the established usability principle of User Control[14].
3. **Trust** increase users' confidence in the system[26]. Trust could also relies on recommendation algorithm[11]. Studies suggested that trust is related to transparency and increase the possibility of interaction with the system.[elfernig2006empirical].

If users find system trustworthy then they are intent to return back to the system[6].

4. **Persuasiveness** convince users to try or buy [26], where as it may increase user evolution of the system. It allow user to gain benefits form the system rather than relied on other individuals.
5. **Effectiveness** helps user to make good decision [26]. Effectiveness is totally depends on recommendation algorithm. It also helps user to evaluate the quality of recommendation according to their preferences and also discard those item, which are not related to taste.
6. **Efficiency** help users make decisions faster [26]. Nielsen describe efficiency is an establish usability principle and explain it is ability of system to help user in fast decision making while selection of best suited item[14].
7. **Satisfaction** is the ability to make system fun while user is interacting with the system [26]. Similarly, providing poor recommendation tends to decrease a user's interest [24] or acceptance of a system[9].

2.1.7 Mobile System

[21]

1. **Device portability** [14].
2. **User mobility** [14].
3. **Wireless connectivity** [14].

General Issues

1. **Resource limitation**[17].
2. **Connectivity**[17].
3. **Battery life** [17].

2.2 Related Work

2.2.1 User's Food Preference Extraction for Personalised Cooking Recipe Recommendation

2.2.2 Knowledge Base Framework for Development of Personalised Food Recommendation System

2.2.3 Interactive Explanations in Mobile Shopping Recommender Systems

2.2.4 Active Learning Strategies for Exploratory Mobile Recommender Systems Interactive Explanations in Mobile Shopping Recommender Systems

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