

# A Context-based Mobile Knowledge Support System for Supporting Foreign Students in China

Xiangpei Hu Khalil Al-mekhlafi Lijun Sun Ziguang Zheng

School of Management, Dalian University of Technology, Dalian City, Liaoning Province 116024, P. R. China

*Email: drhxp@dlut.edu.cn, khelcoo2004@gmail.com*

## Abstract

The idea of Context-based Mobile Knowledge Support System (CMKSS) is to provide three kinds of support based on a user's context and needs, namely, knowledge support, guide support and language practice support. An integrated knowledge representation method to represents the demand profile and supply profile was proposed. An efficient matching algorithm and rule-based reasoning are proposed for matching a suitable knowledge support item. To evaluate the efficiency and effectiveness of the proposed methods, the prototype of CMKSS is implemented. The final results show that CMKSS can efficiently providing the Top-N suitable knowledge items for a user based on the user's needs and contexts.

**Keywords:** Context-based system, knowledge representation, matching algorithm, knowledge support system

## 1. Introduction

Recently, the number of foreign students who come to China to learn Chinese language has risen greatly. However, it is often difficult for them to smoothly learn the language due to the unique characteristics of it, such as its complicated

shapes, different intonations and multiple meanings. Foreign students who live and learn Chinese language in China may face the following three major challenges. (1) Lack of service guide when they go out of campus (for instance, how they can go and get services in hospitals, banks, railway stations, etc.). Sometimes they easily get lost in towns or streets. Hence they need some real-time recommendations (such as the notice of "taking pictures is not allowed here"). (2) Different countries mean different cultures, different public policies, and different ways of dealing with various things. For example, the rules for exchanging foreign currencies or transferring money in China differ from those in other countries. So there are difficulties for foreign students who are not familiar with the policies and rules governing public services. (3) Lack of efficient language learning tools for them to practice language skills in the real world according to their requirements. From language practice point of view, using mobile technology can effectively improve the language practice in any place at any time.

Personalized Language learning, which provides the suitable learning environment anytime, anyplace, and for any ac-

tivity, is greatly influenced by learners' contexts, such as locations and situations. There have been many attempts to utilize the context (e.g. location, time, etc.) features in the field of mobile language learning. Meyer et al. argued that location-aware game scenarios for language learning offer new pedagogical links between formal and informal learning environments, and support language learners in engaging and participating in local environments as social actors with Mobile City and Language Guides [1]. The StudyCell is the bit-sized lessons provided by McNicol et al., which appeals to busy students. These lessons are typically delivered several times a week or even daily, including translations, and they provide options for further context-based applications [2]. TenseITS is a language learning environment that adapts the interaction to the individual learner's understanding provided by Cui et al. It also adapts according to contextual features of the learner's location that may affect their ability to study [3]. Stephen et al. envisioned that providing context-aware learning content is the first step of the ubiquitous learning by finding right collaborative learners, right learning content and right learning services in the right place at the right time [4]. Tseng et al. proposed a mobile environment on PDA for foreigners to learn Chinese, especially for females who came to Taiwan to find their spouses from Southeast Asia [5]. Almekhlafi et al. also proposed a context-aware mobile Chinese language learning approach to providing an appropriate learning item for foreigners based on their contexts [6]. Although these attempts tried to combine the mobility and pervasive computing features to enhance language learning, they lack knowledge-based systems for providing language-learning materials that depend on the background of a learner. In the fields of Decision Support System (DSS) and

knowledge-based systems (KBS), there are a great number of knowledge representation methods with regard to modeling and decision making. Traditional knowledge representation methods include logical, network, procedural and frame-based schemes [7]. Methods extended from traditional ones include Production Rules [8], ontology [6][9], and Hierarchical (Tree-like) [10] methods, etc. These knowledge representation methods may be used to represent the knowledge in the knowledge support system for supporting foreign students.

There are many forms of matching methods. One of the main functions of them is to match one kind of agent with another which called two-sided matching, where the two-sided refers to the fact that agents in such an environment belong, from outset, to one of two disjoint sets [10][11]. Liu and Greer proposed a framework for the selection of individualized learning object, called Eliminating and Optimizing Selection (EOS) [12]. Takasu proposed a dynamic programming algorithm to find the occurrences of each word in a text, where the string similarity is measured by a statistical similarity model that enables a definition of the similarities in the character level and edit operation level [13]. Fabien, Bellahsene and Roche proposed a hybrid method, Approxivect, to measure the similarity between two elements of different schemas [14]. Chang and Zheng investigated the extraction of knowledge element from learning resources by machine. They employed the ECOC method to construct the multi-class classification model for the extraction of knowledge element [12]. Alian proposed the formalization for the Eliminating and Optimizing Selection (EOS) framework [15]. Most of these literatures concerned one-to-many matching methods. However, due to the capability limitations of mobile devices, they cannot be used directly. Furthermore, as

contextual information is timely changeable, knowledge and contextual information should be taken into account when matching a demand with a supply. However, the classical keyword-based string matching cannot work when the input string is different from the records in the database, and the content-based matching methods aren't effective in our case due to the complex structure of the user demand and knowledge elements. So, it is necessary to represent the knowledge of demand and supply and establish a new matching algorithm that can meet the above mentioned requirements by matching the demand profile and supply profile. In this paper, we present a Context-based Mobile Knowledge Support System (CMKSS) for supporting foreign students with three kinds of support, knowledge support, guide support, and practice support. An integrated representation method for representing Demand Knowledge (DK) and Supply Knowledge (SK) is proposed. The proposed matching method includes matching algorithm and rule based reasoning, where the former is to match the demand profile with supply profile to provide Top-N suitable knowledge or practice support items, and the latter is to match suitable guide support items.

The rest of the paper is organized as followings. In section 2, we present the CMKSS framework. Section 3 introduces the knowledge representation. Section 4 presents the matching algorithm of knowledge and practice support. Section 5 introduces the rule-based reasoning of guide support. Section 6 presents the implementation of CMKSS prototype. Finally, we conclude in section 7.

## 2. CMKSS Framework

According to the challenges that the foreign students may face during their living and studying Chinese in China, we pro-

posed a Context-based Mobile Knowledge Support System (CMKSS).

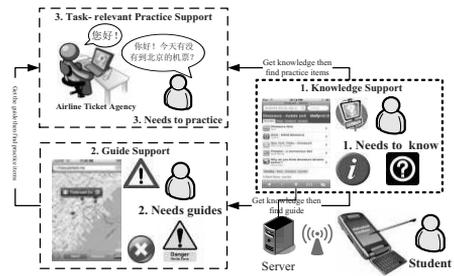


Fig. 1: Three Functions of CMKSS Approach.

As shown in Fig. 1, CMKSS provides the following three functions. (1) Knowledge support: this support depends on the current task where the student sometimes needs the knowledge about a particular task. For example, the knowledge about how to buy an airline ticket in China in order to avoid the failure of getting service. Four knowledge subjects related to a task are described. They are task definition, task features, task requirements and task procedures. (2) Guide support: a foreign student who wants to fulfill any task around the city (such as, buying an airline ticket) maybe need some guides. Guide support can be warnings, attentions, suggestions, task-oriented nearest places, and road-guide maps. (3) Practice support: the key point of the CMKSS approach is to provide personalized language practice on the current task according to the learner's needs. Practice support means providing right language practice contents (including text, video, audio, or image) at the right place and time, and based on the current task.

As thus, the framework of the CMKSS includes the five major components, human-computer interfaces, demand knowledge subsystem, supply knowledge subsystem, demand and supply matching subsystem, and knowledge management

subsystem, as shown in Fig.2. As knowledge is the basic element in the system for accurately acquiring user requirements and determining the available knowledge, guide, or practice contents for providing suitable support to a user, knowledge representation and matching method are the key points for implementing the CMKSS. Thus in this paper, we focus on demand and supply knowledge representation and matching algorithm.

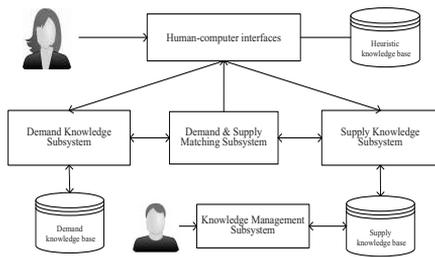


Fig. 2: CMKSS Framework.

### 3. Knowledge Representation

To define a learner's surroundings and the attributes of learning contents, many kinds of knowledge need to be represented. It's hard, even impossible, to use a single existing knowledge representation method to represent the diversified knowledge elements for the complicated problems. It's necessary to employ different types of knowledge structures to capture different types of information. Hence we propose an integrated representation method for representing the demand and the supply knowledge as shown in Fig. 3.

#### 3.1. Demand Knowledge Representation

In this part we present the demand knowledge representation components from the aspects of user-system

interaction, contexts acquisition, and demand profiling. The output is an XML file that examines the whole requirements of the learner [16].

#### 1) User-system Interaction

Some of contexts need to be defined by the user-system interaction process, e.g. current task context. The current task means what the learner wants to do now, so it is necessary to use the interaction to achieve the common understanding between the learner and the system. The interaction process is based on the concept taxonomy in the system. The learner firstly inputs the query by a keyword. And then, based on the concept taxonomy, the system will respond with some related concepts (i.e. the similar concept, parent concept, subconcept). The interaction process aims to define the context of the current task.

#### 2) Context Acquisition Mechanism

The contexts are the key part of demand knowledge representation. Eighteen context elements are used to determine the learner's whole requirements categorized as learner contexts, activity contexts, environment contexts, and device contexts. Some of these contexts describe the learner's profile, and others describe the learner's surroundings, device used, and activity at current time. The context acquisition is to detect and analyze contextual information. Some contexts are manually inputted, and some are automatically detected from external hardware sensors, GPS receivers or software sensors like system timer, and others need user-system interactions, such as the contexts on describing the current task.

#### 3) Demand Profiling Mechanism

Demand Profiling (DP) is a set of contexts that describes the learner's current situation and surroundings. After

detecting the context information from various sources, we employ the rule-based method to determine the individual contexts for every task. The rule base contains a set of rules in the form of IF-THEN sentences. Each rule determines the importance of contexts for a task. Then, we utilize the Document Type Definition (DTD) to define the legal

building blocks of the demand profile with XML document. With the DTD, we can segment the contexts to fit the three kinds of supports (for example, the DP for ticket-buying task will be divided into three parts, namely guide, knowledge, and practice for buying a ticket). Fig. 4 and Fig. 5 are the segments of a simple DTD and an XML of a demand profile.

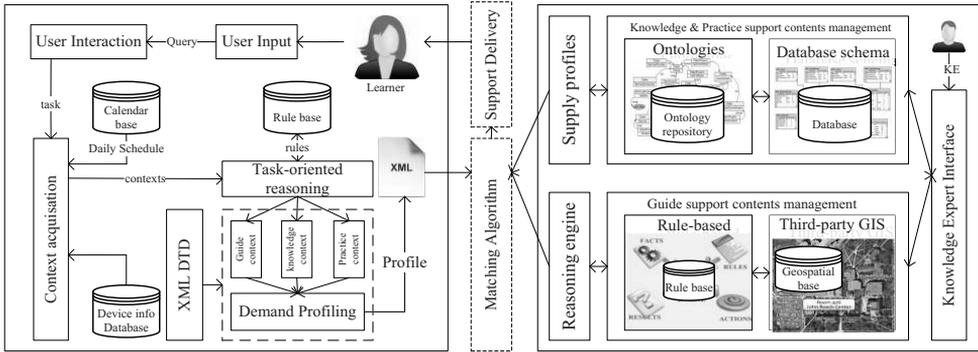


Fig. 3: An Overview of the Integrated Representation of the Demand and the Supply Knowledge.

```
<!ELEMENT SupportKind (GuideSupport,
KnowledgeSupport, PracticeSupport)>
<!ELEMENT GuideSupport (LearnerCon-
texts,EnverionmentContexts,
ActivityContexts,DeviceContext)>
<!ELEMENT LearnerContexts (UserInforma-
tion,AuthenticationInformation)>
<!ELEMENT UserInformation (Use-
rID,Name,Birthday,Chineseelevel,Gender,native
anguage.ChineseLanuaaeLevel.favorite)>
```

Fig. 4: DTD of DP.

The result of demand profiling is the demand profile as follows:

**Definition 1. Demand Profile (DP):** A demand profile is a set of contexts that describes the user’s current situation and surroundings, described by the following formula.

$$DP_i = \{UI_i, CT_i, D_i, NL_i, 2L_i, mode_i, 2LL_i, SK_i, SS_i, RC_i, CL_i, CT_i\} \quad \text{where } i = 1, 2, 3, \dots, n.$$

```
<?xml version="1.0"?>
<!DOCTYPE demandProfile SYSTEM "demandPr
<guideSupport >
<LearnerContexts>
<UserInformation>
<UserID>104</UserID>
<Name>khalil</Name>
<Birthday>1981.12.01</Birthday>
<environment contexts>
.....
```

Fig. 5: XML of DP.

$UI_i$  is the user ID.  $CT_i$  is the current task context.  $D_i$  is the mobile device used.  $NL_i$  is the native language.  $2L_i$  is the second language.  $mode_i$  is the user mode.  $2LL_i$  is the second language level.  $SK_i$  is the support kind.  $SS_i$  is the support style.  $RC_i$  is the reading capability.  $CL_i$  is the current location context and  $CT_i$  is the current time.

### 3.2. Supply Knowledge Representation

This part focuses on representing the knowledge and practice support contents, and the guide support contents. Specifically, we employ the ontology technology and database schema to represent the knowledge and practice support contents, and use the third-party GIS system and production rules to represent the guide support contents.

**1) Knowledge and Practice Contents Representation**

Knowledge and practice contents base is a storage place which includes four kinds of multimedia contents, namely texts, videos, audios, and images. Knowledge Support (KS) and Practice Support (PS) can be indicated by four subjects respectively.

$$KS = \{tk_d, tk_r, tk_f, tk_p\} \text{ and}$$

$$PS = \{tp_d, tp_r, tp_f, tp_p\}.$$

Where,  $tk_d$  is task knowledge definition.  $tk_r$  is task knowledge requirements.

$tk_f$  is task knowledge features.  $tk_p$  is steps to achieve the task.  $tp_d$  is the practice on the task definition.  $tp_r$  is the practice on the task requirements.  $tp_f$  is the practice on the task features.  $tp_p$  is the practice on the steps to achieve the task.

**OWL Ontology.** Gruber defined ontology as follows: “An ontology is an explicit specification of a shared conceptualization” [17]. We use OWL ontologies for two purposes. One is to enhance the efficiency of the matching process based on the current task. The other one is to enable users to choose the available knowledge or practice support subjects. Two ontologies, task ontology and support ontology, are used. Based on the ontology hierarchy with is-a relations defined preliminarily, we create has-a relations for the preparation of matching in order to overcome the difficulties of the connection, query, and reasoning in the two ontologies. Besides, we also created new defined classes [18].

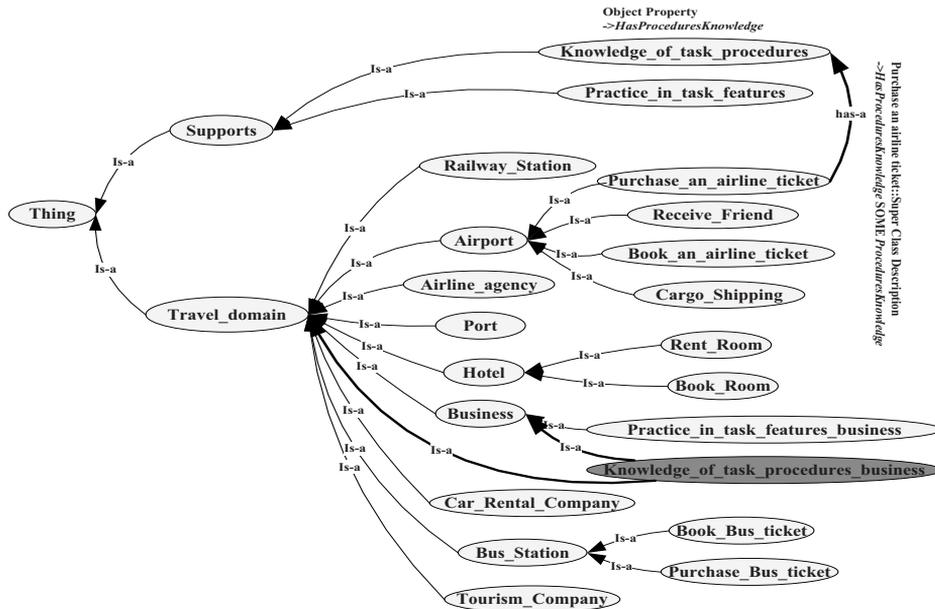


Fig. 6: OWL Ontologies.



which relates to the locations and the information about the locations, for example, the location name and destinations, the warnings at the location, the direction between two locations, the route guide between two locations. Map2mobile Image Generation is responsible for extracting the map guide for two locations (the current location and the target location), and then converting this map to a mobile image and sending it to the learner as the map guide. Due to the limitations of mobile devices, we suggest that the output image should contain the following features, Image Size=200x300, Color Depth=24bits, Image Format=PNG, and Image File Size=Approx 20KB, etc. The production rules expressed by the form of “*IF conditions THEN action*” judge which guide subject should be provided to the learner depending on his/her situation. Five contexts, current location, target location, time, calendar, and current task, are taken into account during representing the guide contents in order to match this part of demand profile with the reasoning rules. For instance, according to the geo-information stored in GIS database and the production rules, the guide support can be a warning like “No smoking allowed here” or an attention like “Your visa will expire in a week”.

The result of the representation for knowledge, guide and practice contents is the supply profile as follows.

**Definition 2. Supply Profile (SP):** a supply profile is a set of features used to index the knowledge items in knowledge base, described by the following formula.

$$SP_i = (KI_i, TN_i, MK_i, L_i, LL_i, SK_i, ER_i, IS_i)$$

where  $i = 1, 2, 3, \dots, n$ .

$KI_i$  is the Knowledge items’ ID.  $TN_i$  is the Task Name.  $MK_i$  is the Multimedia Kind.  $L_i$  is the Language of the knowledge item.  $LL_i$  is the Language Level.  $SK_i$  is the Support Kind.  $ER_i$  is the Expected Reading.  $IS_i$  is the Item Style.

#### 4. Matching Algorithm for Knowledge and Practice support Items

As shown in Fig. 3, after defining the demand profile and supply profile by using an integrated knowledge representation, the matching algorithm that can provide the Top-N suitable knowledge, guide and practice support items to the user will be presented in this section.

##### 4.1. Framework of the Matching Algorithm

The matching algorithm is composed of the components of rule-based filtering, similarity matching, and suitability matching. Among which the rule-based filtering component is to remove irrelevant support items by constructing the candidate list of support items, which will be the input of the next step. The similarity matching component is to construct the most similar support items as the input of the next step. And finally, in the suitability matching component, predicate logic is used to evaluate the Top-N suitable support items. We illustrate these three components in detail as follows for matching knowledge support items or language practice items.

##### 4.2. Matching Algorithm

###### 1) Clustering Related Support Items.

In the rule-based filtering component, we use four contexts of DP and three attributes of the SP to remove irrelevant items. As shown in Fig. 8,  $CT_i, D_i, NL_i, 2L_i$  from DP corresponding with  $TN_i, MK_i, L_i$  from SP are used to

reduce the number of irrelevant items. For instance, to support the user who needs knowledge about “internet banking”, the support items of “buy food” will

be omitted. Here we use rules to facilitate the process of filtering the candidate support items. The candidate list will be prepared based on the following function.

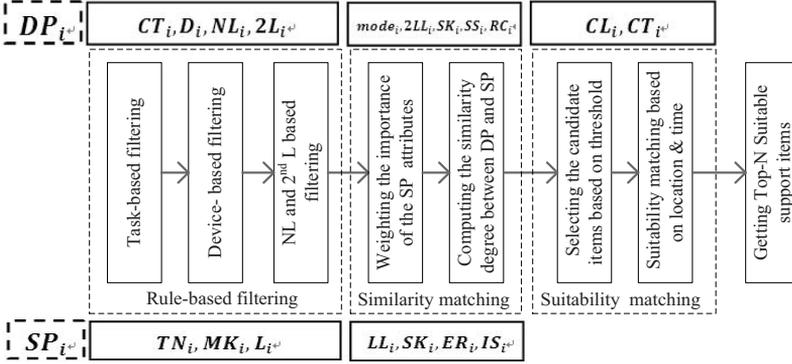


Fig. 8: Framework of Matching Algorithm.

```

{
  ∀ i ∈ support items
  IF i ∈ (candidate1 ∩ candidate2
          ∩ candidate3
          ∩ candidate4)
  THEN i ∈ relevant items list
  ELSE i ∈ irrelevant items list
}

```

The result of this phase is a list of candidate support items which will be the input of the similarity-based matching component.

## 2) DP and SP Similarity Computing

To extract the support item, which has the attributes of  $(LL_i, SK_i, ER_i, IS_i)$  in SP, which is similar to the contexts of  $(2LL_i, SK_i, SS_i, RC_i)$  in DP, following steps should be realized in the similarity-based matching component. Firstly, we use  $(mode_i \text{ context})$  to define the weights of SP attributes, which reflect the importance of user contexts. The value of  $mode_i$  may be one of (Details, Easy, Quick) depending on the user needs. For example:

```

IF ( mode_i = details) THEN
{
  W of SK_i = 4/4, W of IS_i = 3/4, W of LL_i =
  2/4, W of ER_i = 1/4
}

```

Secondly, we need to compute the match degree between the DP contexts and SP attributes.

After defining the weights of SP attributes, we use the following formula to calculate the similarity between the DP and SP:

$$\text{Sim}(\text{DP}, \text{SP}) = \frac{w_1 * p_1 + w_2 * p_2 + \dots + w_n * p_n}{w_1 + w_2 + \dots + w_n} \quad (1)$$

Where  $w_n$  is the weight =  $\frac{I_n}{N}$ ,  $I_n$  is the interest degree (1 – 4 in the example above), and  $N$  is the number of attributes for computing the similarity.

$p_n$  is the degree of the match between the DP contexts and SP attributes, where :

$$p_i = \begin{cases} 0, & \text{if } DP \text{ context} < SP \text{ attribute} \\ 1 & \text{if } DP \text{ context} = SP \text{ attribute} \\ \frac{SP}{DP} & \text{if } DP \text{ context} > SP \text{ attribute} \end{cases} \quad (2)$$

After determining the weights of SP attributes and computing the degree of the match between DP and SP, we will obtain a list of support items with their similarity degrees to a user's needs. This list is the input of the suitability matching component, which takes into account the user location and time that can affect the evaluation of the suitable support item.

### 3) Suitability Matching of Support Items

To get the suitable support item from the list of support items, which is obtained by the suitability matching component, it is necessary to calculate the similarity threshold for defining the most similar area to the user needs, and then use predicate logic to decide which is the Top-1 suitable support item and Top-4 options based on the user's current location and current time.

**Definition 3. Similarity threshold:** similarity threshold is a lower bound for the support items list which is similar to the DP that takes the value  $T \in [0, 1]$ . It is impossible to predefine this value due to the insufficient results. In this part we propose the criteria for getting the value of the similarity threshold. Let  $S = SP_1, SP_2, \dots, SP_n$ , where  $n$  is the total number of the support item candidates in the list, and  $MK_i = \{\text{video, audio, image, text}\}$  is the multimedia kind of the support items. Firstly, we calculate the max similarity of all support items which include all kinds of multimedia by the functions of  $T_1, T_2, T_3,$  and  $T_4$ .

$$T_1 = \begin{cases} \max(\text{sim of } SP_i), & \text{if } MK_i = \text{"video"} \text{ where } i \geq 1 \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

$$T_2 = \begin{cases} \max(\text{sim of } SP_i), & \text{if } MK_i = \text{"audio"} \text{ where } i \geq 1 \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

$$T_3 = \begin{cases} \max(\text{sim of } SP_i), & \text{if } MK_i = \text{"image"} \text{ where } i \geq 1 \\ 0 & \text{Otherwise} \end{cases} \quad (5)$$

$$T_4 = \{\max(\text{sim of } SP_i), \text{ if } MK_i = \text{"text"} \text{ where } i \geq 1\} \quad (6)$$

The similarity threshold  $T$  will be determined by the following function.

$$T = \min \{T_1, T_2, T_3, T_4\} \quad (7)$$

After we define the similarity threshold, we can get the candidates of support items for the processes of determining Top-1 and Top-4 support items.

**Definition 4. Top-1 suitable support item:** It refers to the support item with suitable multimedia kind which meets the user's needs based on the location and time information.

$$\text{Top} - 1 = \begin{cases} \text{video} & \text{depending on the reasoning result} \\ \text{audio} & \text{depending on the reasoning result} \\ \text{image} & \text{depending on the reasoning result} \\ \text{text} & \text{depending on the reasoning result} \end{cases} \quad (8)$$

To select the Top-1 (i.e. the most suitable kind of multimedia), the locations, like road, home, on the sea, coffee shop and so on, and the time periods will be classified, based on which the rules and facts will be established in the knowledge base. For example:

**IF** current location = road and time =12:00 **THEN** multimedia kind= text.

**Definition 5. Top-4 suitable support items:** The support items with maximum similarity for video, audio, image, and text compose the list of the best four support items in the following function:

$$\text{Top-4} = \{\max(\text{sim of video}) + \max(\text{sim of audio}) + \max(\text{sim of image}) + \max(\text{sim of text})\} \quad (9)$$

### 5. Rule-based Reasoning for Matching Guide Support Items

Six rule-based reasoning steps will be tried to find one or more guide support items depending on the importance degree from the warnings, nearest locations, attentions, suggestions, and road guide respectively as shown in fig. 9. The guide demand profile (GDP) will combine 6 kinds of context (User, Task,

Current Location, Current Time, Calendar Schedule, and Target Location Context) in the matching.  $GDP=U+T+CL+CT+CS+TL$ .

In this matching we need to deal with GDP, GIS database, reasoning and Knowledge base. Sometimes only the

GDP input and GIS database are used to get the guide subject, like warnings. Some other guides may need both the GIS database and the knowledge base to get the guide subject, like attentions and suggestions.

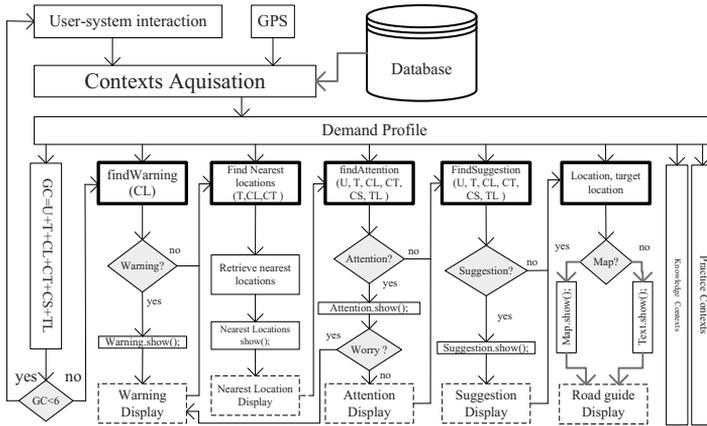


Fig. 9: Guide Support Reasoning Process.

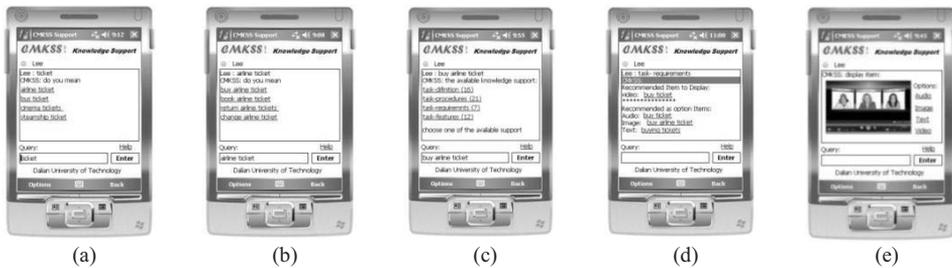


Fig. 10: The CMKSS Prototype Interfaces.

## 6. CMKSS Prototype Implementation

CMKSS is implemented based on Client/Server Structure taking advantage of the internet and .NET platform. We used protégé 0.4 for building the ontologies. Ontology reasoning has been done in FaCT++, The whole prototype is implemented in the platform of Visual studio.net 2008 for development and test.

CMKSS-client application is installed in a mobile phone and CMKSS-server is set up at the server of the support center. We use an example, as shown in Fig 10, to indicate how the learner named Lee get a suitable knowledge support items for the task of buying airline ticket from the CMKSS prototype. After Lee sign in to the CMKSS application, he can update his profile. We assume that Lee needs to buy airline ticket and input "ticket" (see

Fig. 10(a)). The system returns some related concepts “*airline ticket, bus ticket, cinema ticket, ...*”. Lee chooses “*airline ticket*” (see Fig. 10(b)). The system returns some related concepts “*buy airline ticket, book airline ticket, return airline ticket, ...*”. Lee chooses “*buy airline ticket*” (see Fig. 10(c)). Based on ontology, the system will display the available knowledge subjects for the *buy-airline-ticket* task. Lee chooses one of the available knowledge subjects “*task-requirements*” (as shown in Fig. 10(d)). The system will display the recommended item and the option items. Fig. 10(e) shows the video contents as the displayed item, which discusses the requirements for buying an airline ticket. If Lee wants to see another item, he can choose one of the option items.

## 7. Conclusions

This paper presents a Context-based Mobile Knowledge Support System (CMKSS) for supporting foreign students in China. The idea of CMKSS is to provide three kinds of support, knowledge support, guide support and language practice support, based on the user context and needs.

From the academic aspect, in order to achieve the three functions of CMKSS, this research presented an integrated representation of demand and supply knowledge for Chinese mobile knowledge support for supporting foreign students in China. The proposed knowledge representation method can accurately define, acquire, and analyze a learner’s requirements and the available support contents for providing a suitable support contents for him/her. Furthermore, as contextual information is timely changeable, fast matching is necessary in the real world. Otherwise, the real value of the context information will be lost. The capability limitations of mobile devices, like memo-

ry, storage, multimedia display, etc. make it difficult to match a suitable support item to fit the current user’s needs and devices used. The research proposed a matching method that can overcome the above mentioned deficiencies. The matching method is a tool for context-based knowledge support based on the demand profile and supply profile. From the industry aspect, the prototype presented by the research has a great potential market, as China is becoming one of the largest mobile business markets for its great amount of mobile devices and users, and more and more foreign students are coming to China who may need a system of this kind. From the culture diffusion aspect, the system will also facilitate the diffusion of the Chinese culture. With the fast development of economy and society, China attracts not only foreign students to pursue education, but also many foreign tourists who want to know the real Chinese culture. Under the trends of mobile business and flourish of business models, the CMKSS is the first context-based knowledge support system for foreigners in China. It will be a useful tool to help foreigners to study and travel freely in China and know more about Chinese culture. As the matching algorithm, especially the similarity matching component considers only one user context (i.e. user’s mode), our future work is to improve the similarity measure by considering several user contexts in order to more accurately define the candidate list of support items.

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