Natural language interface for information management on mobile devices

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A natural language interface (NLI) enables the ease-of-use of information systems in performing sophisticated human–computer interaction. To address the challenges of mobile devices to user interaction in information management, we propose an NLI as a promising solution. In this paper, we review state-of-the-art NLI technologies and analyse user requirements for managing notable information on mobile devices. To minimize any technical difficulties arising from developing and improving the usability of NLI systems we develop general principles for NLI design, which fills in a gap in the literature. In order to satisfy user requirements for information management on mobile devices, we innovatively design NLI-enabled information management architecture. It is shown from two usage scenarios that the architecture could lead to reduced effort in user navigation and improved efficiency and effectiveness of managing information on mobile devices. We conclude the article with the implications of this study and suggestions for future direction.

Keywords: Natural language interface; Information management; Mobile device

1. Introduction

The advent of mobile devices is having a profound impact on the way people communicate, as well as on the user interaction paradigm for information management that was traditionally completed with paper-based media and desktop personal computers (PCs). Powered by wireless communication technologies, mobile devices offer the convenience for people to access information at the right place at the right time. Thus, they have great potential in a wide range of applications such as information management.

Information management is defined as acquiring, organising, disseminating and using information of value to support the routine activities of individuals and organisations. Specifically, we take the individual’s perspective throughout the discussion in this paper. Accordingly, information here refers to all types of information that are notable and of archival value to individuals. A variety of applications, including calendar, contact, memo and so on, have been built to support information management on mobile devices. However, the potential benefit of mobile devices to information management is undermined by the challenges of information input and navigation on mobile devices (Samaras 2002, Paelke et al. 2003, Sarker and Wells 2003). The current practice of managing information on mobile devices entails users adapting to unique interfaces of various applications and accommodating the system constraints on how and where to enter information. In order for information management systems to take advantage of the convenience of handheld devices, they should accept user input and provide information to the user in the right format (Zhang 2003). This highlights an emerging issue of improving the efficiency and effectiveness of information management on mobile devices.

Among the revised set of usability heuristics for user interface design (Nielsen and Mack 1994), *match between system and the real world* states that the system should speak the users’ language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. User’s language includes both verbal (e.g. English) and nonverbal languages (e.g. gestures). Natural language, referred to as a human written or spoken language, is a

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typical verbal language. A natural language interface (NLI) exemplifies the above design principle by narrowing the gap between human languages and diverse information systems. An NLI is a user interface that allows people to interact using a human language, such as English or Chinese, as opposed to a computer language, command line interface, or graphical user interface (GUI) (Thompson and Ross 1987). It essentially provides an abstract layer between users and computers. NLIs have been used for a variety of applications including database query, question–answering, command–control, personalisation and so on (Kelley 1984, Novell 1996, Paek and Jeon 1997, Darby 1998, Lai et al. 2002, Yates et al. 2003). There are at least two limitations in today’s applications of NLIs. One is that NLI applications have primarily focused on PCs, but ignored handheld mobile computers. With the advance of wireless technologies and computer hardware, the capacity of mobile devices reaches a comparable range to that of PCs. As a result, it is feasible to develop NLIs for mobile devices. The other one is that NLIs have rarely been discussed in the context of information management domain. Our analysis of the impact of NLIs on information management reveals multifold potential benefits. Given the importance of information management to our daily life and work, there is a need to tap into the potential of NLIs in information management. The investigation of NLIs for information management on mobile devices could expand our knowledge of NLIs to mobile devices, advance approaches to NLI design, and improve the efficiency and effectiveness of information management in practice.

The objective of this study is to examine NLIs and their role in information management on mobile devices. An NLI is a broad concept covering many technologies. In this study, we first review its existing applications and enabling technologies. Drawing on the extant literature and our experience, we develop general principles for NLI design. To support information management, we analyse the requirements of NLIs for information management on mobile devices and design an NLI-enabled system to satisfy user requirements. Finally, we discuss benefits and challenges of the proposed NLI system and suggest future directions.

2. Background

The promise of NLIs in bringing computers to human use by enabling computers to understand human language has motivated a lot of research and applications for a long time, paralleling the evolution of computers.

2.1 The applications of NLIs

Based on previous work on NLIs, we develop a taxonomy of their applications. As shown in figure 1, the applications of NLIs are classified into five categories: natural language database query, question answering, command and control, Web personalisation and information management.

The potential of NLIs was first demonstrated with LUNAR (Woods et al. 1972) – a natural language dialogue system that responds to query about the rock samples brought back from the Apollo missions to the moon. It represents the application of an NLI in a realistic application domain, which inspired a stream of research on natural language query to database (e.g. Hendrix et al. 1978, Kaplan 1984, Yates et al. 2003). A database system equipped with an NLI can directly interpret a natural language query instead of a specialised database query. For example, a natural language query, ‘What are the total

![Figure 1. A taxonomy of applications of NLIs.](image)
sales of heaters in November of 2005?”, is translated into the following complex database query:

```
select sum(price*quantity)
from sales, products
where product_type = 'heater' and sale_date <= '30-Nov-2005' and sale_date >= '1-Nov-2005'
group by product_type.
```

NLIs have been extended to answer questions from users by accepting and processing natural language and responding in natural language. This is particularly useful for improving customer service functions in an e-business. In such a case, customers have the flexibility to issue intuitive and natural commands or queries without going through complex menus and multiple difficult interfaces (MobileInfo 2001). Customers can also be assisted automatically by system’s response with relevant help documents. For example, Ask Me (Novell 1996) is a system that allows software companies to gain access to any new or existing Windows help system as well as other major help authoring systems. NLIs are also developed to help users navigate the Web (Paek and Jeon 1997).

In addition to meeting user information needs, an NLI allows users to control systems by issuing natural language commands in order to carry out directions and execute business transactions. For example, different household appliances have different interfaces and require different input methods and commands. With the assistance of an NLI, users can easily control the household appliances by speaking or typing in simple English to a single control device connected to those appliances (Yates et al. 2003).

Natural language has recently been viewed as a compelling enabling technology for personalisation (Zadrozny et al. 2000), which allows each user to interact with the system in his or her own words, rather than using one of a small number of preset ways to interact. The personalisation not only improves a system’s performance in interpreting natural language, but also has far-reaching implications for international communication across different languages.

The application of NLIs to information management remains very rare. CAL (Kelley 1984) supports computer-naive business professionals in managing their personal calendars. It understands the English language and takes charge of scheduling and managing the users’ time. CAL users do not need to go through formal training or thick instruction manuals. MA (Lai et al. 2002) is an automated assistant that provides message notification and calendar management. It aims to support the pressing communication needs of mobile workers by simulating human–human conversation with a voice interface. The above two applications of NLIs are close to the objective of the current research that is to apply NLIs to information management on mobile devices. However, the first study (Kelley 1984) solely focuses on calendar management on PCs. With the revolution of computer and wireless technologies in the past two decades, some user information management needs have changed over time. Although the second study (Lai et al. 2002) takes mobility into concern, it mainly addresses information access, but ignores those important issues of information management such as information classification, linkage and integration. In addition, it is difficult to overcome the technological hurdle of speech recognition.

2.2 Benefits of NLIs

The Literature reviews mentioned in Section 2.1 have revealed a number of benefits of NLIs. These advantages in relation to traditional menu-based interfaces are listed in Table 1. For example, for mobile devices with a small amount of screen space for display, there is a real necessity of being economical in consuming screen space. NLIs are superior to menu-based interfaces in their ability to accommodate limited input/output space easily – the less natural the semantics, the harder it will be to remember (Coates 2002). NLIs represent a natural way for users to interact with a system in a consistent manner. Some things can be accomplished more easily with NLIs (Brennan 1990), including negation, quantification, searching very large databases, distinguishing individuals from kinds, filtering and requesting information in creative ways beyond those specified by the interface designer, building up a complex query that involves multiple actions.

There is a growing interest in the use of natural language, both spoken and written, in intelligent multimodal and multimedia interfaces (Shneiderman and Plaisant 2005). Speech-based interfaces can further increase the speed of human–system interaction by allowing hands-free human–computer interaction that is not possible when using a keyboard and mouse. They further increase the accessibility of people with physical impairments (Trewin and Pain 1999, Sears and Young 2003). The advantage of voice-based NLIs becomes even clearer when it is applied to mobile handheld devices with limited screen space (Lai et al. 2002) or when users are in motion. However, given the substantial challenge of speech recognition systems in the context of large-vocabulary speaker-independent continuous spontaneous speech, the scope of this study is primarily constrained to the text modality only.

The promises of NLIs are undermined by many challenges of implementing them, which are discussed in Section 3.

2.3 Fundamental technologies supporting NLIs

Natural language processing technologies underlie NLI systems. Natural language processing aims to understand what a word means, how to combine words to make
sentences, what a sentence means in different contexts, and so on. To answer questions or to participate in a conversation, an NLI system should not only know the structure of the language being used, but also have the knowledge about the world in general and the conversational settings in particular. Forms of knowledge that can support NLIs are described in table 2. The technological foundation of NLIs is shown in figure 2.

Each natural language processing technique is enhanced by various forms of knowledge support. In particular, phonetic and phonological analyses aim to identify the boundaries of phonetic segments in speech input, converting them to a sequence of words. Morphological analysis recognises the roots, prefixes and suffixes of a word to determine its part-of-speech. Syntactic analysis parses sentences into grammatical components based on a specific set of grammar rules. Semantic analysis prescribes meaning to the parsed components and then combines the lexical units together to form a meaning for the entire sentence, which usually follows specific semantic grammar. Discourse and pragmatics analyses go beyond the boundary of a sentence by taking into account contextual factors in understanding the meaning of sentences (Rich and Knight 1991). The contextual factors include references, speech acts, idioms, and so on. They focus on larger language units such as conversational exchanges or written texts (Stubbs 1983). Common-sense making, as we term it here, represents the ultimate goal of natural language processing to equip computers with human language skills, especially reasoning based on world knowledge. Among the six layers of analyses in figure 2, the middle four layers are frequently applied to developing NLIs to various degrees. The bottom layer – phonetic and phonological analysis – is mainly applicable to speech-based NLIs. The top-layer – common sense making – is rarely available in NLIs, for how to capture the world knowledge and model inference process as the human brain does is an ongoing research issue. In addition in an actual NLI system, the boundaries between different layers are sometimes blurring.

### Table 1. Comparisons between NLIs and menu-based interfaces.

<table>
<thead>
<tr>
<th>Features</th>
<th>NLI-based solutions</th>
<th>Menu-based solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency: efficient</td>
<td>Users can combine multiple actions into a single</td>
<td>Users navigate through screens of forms or menus in order to reach the desired goal.</td>
</tr>
<tr>
<td>information access</td>
<td>command in natural language.</td>
<td>Users search through menus to find appropriate</td>
</tr>
<tr>
<td>Usability: easy to learn and</td>
<td>Users do not have to memorise specific</td>
<td>commands. Different menu structures and options from different applications demand</td>
</tr>
<tr>
<td>keeping consistency</td>
<td>commands for individual applications, which can reduce users' cognitive effort and</td>
<td>cognitive effort from users, who need to adapt</td>
</tr>
<tr>
<td>Flexibility: free of choices</td>
<td>improve learning curve. In addition, the system matches the real world.</td>
<td>themselves to individual applications.</td>
</tr>
<tr>
<td>Economy: space conscious</td>
<td>They allow a wide range of phrases and</td>
<td>Users are required to access the system in a fixed</td>
</tr>
<tr>
<td></td>
<td>association between different phrases and</td>
<td>manner by following predefined rules.</td>
</tr>
<tr>
<td>Expressivity: rich request</td>
<td>It takes minimum screen space to support the input and output of natural language.</td>
<td>Standard graphical and menu interfaces typically consume additional screen space.</td>
</tr>
<tr>
<td>representation</td>
<td>Natural language is rich in general, including</td>
<td>Users’ requests are transformed into constrained</td>
</tr>
<tr>
<td>Evolution: incremental</td>
<td>representing users’ requests.</td>
<td>and application-specific format.</td>
</tr>
<tr>
<td>learning</td>
<td>Natural language models can be improved by</td>
<td>The menus are predesigned to perform specific functions. Given a user’s request, a</td>
</tr>
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<td></td>
<td>learning users’ language patterns from their input and feedback. As such a system</td>
<td>particular menu is selected and the same output is expected.</td>
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### Table 2. Different forms of knowledge in support of NLI (adapted from (Allen 1995)).

<table>
<thead>
<tr>
<th>Forms of Knowledge</th>
<th>Description of Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonetic and phonological</td>
<td>Knowledge of the sounds of words.</td>
</tr>
<tr>
<td>knowledge</td>
<td></td>
</tr>
<tr>
<td>Morphological knowledge</td>
<td>Knowledge of different words that can be derived by adding suffixes to a root word.</td>
</tr>
<tr>
<td>Syntactic knowledge</td>
<td>Knowledge of the structure of a sentence regarding how different words can be joined to</td>
</tr>
<tr>
<td></td>
<td>make a sentence.</td>
</tr>
<tr>
<td>Semantic knowledge</td>
<td>Knowledge of context-independent meaning concerning what each word means and what a</td>
</tr>
<tr>
<td></td>
<td>sentence means when these words are put together.</td>
</tr>
<tr>
<td>Pragmatic knowledge</td>
<td>Knowledge of context-dependent meaning by studying how a sentence can be used in</td>
</tr>
<tr>
<td></td>
<td>different situations.</td>
</tr>
<tr>
<td>Discourse knowledge</td>
<td>Knowledge of how the immediately preceding sentences affect the interpretation of the</td>
</tr>
<tr>
<td></td>
<td>next sentence.</td>
</tr>
<tr>
<td>World knowledge</td>
<td>General Knowledge to maintain the conversation.</td>
</tr>
</tbody>
</table>
Natural language is inherited with ambiguity, which poses significant challenges to all of the above-mentioned techniques.

3. Challenges and principles for NLI design

To satisfy users, NLIs are expected to interpret their requests and questions correctly. Language communication errors and mistakes in some areas such as aviation could mean the difference between life and death. Even in a routine application of an NLI such as information management, misinterpretation of a search request into a deletion request by forming an inappropriate query could erode the user’s trust and render the NLI unusable. Thus, misinterpretation should happen very rarely, if at all. By gaining insight into the challenges of developing NLI systems, we can identify better solutions to address those challenges. In particular, we develop general principles of NLI design to resolve some of the issues.

3.1 Challenges for developing and deploying NLIs

Despite the promising benefits of NLIs, they have yet to become a pervasive technology in business, organisation and an individual’s daily activities. Much of the current state is attributed to the challenges of developing and deploying them. We summarise the challenges into three perspectives: technology, knowledge and usability.

Technology perspective

- Unlike relational data or other types of tagged data, text in natural language has no specific structure or format, making it difficult to process. Natural language contains several levels of ambiguity: lexical, syntactic, semantic and pragmatic. The ambiguity and resulting possible errors reduce the consistency and reliability of NLIs. For example, identifying names and correlation between names can be challenging: for example, Lincoln refers to the last name in ‘Lincoln, Abraham’ and a city in ‘Lincoln, Nebraska’.
- To compensate for users who often do not have the knowledge to describe the request they are posing in precise terms, NLIs must deal with a significant amount of variation in the choice of words and sentence structures. Given the plenty of information disseminated on the Web using languages other than English, it is even more complicated to develop a systematic approach to processing multilingual text documents, for each language tends to have a different syntactic structure and requires specialised semantic interpretation.
- It is technically challenging to derive a sufficiently rich representation to capture the relationship between objects described in the text and to facilitate autonomous processing. Such information loss could lead to misinterpretation.

Knowledge perspective

- It is important to refer to contextual information in interpreting words, phrases and sentences. However, what kind of context is useful, how much context should be captured, how to capture the context, how to reduce computation overhead and resolve potential contradiction between different contextual factors are all open issues.
- It is an unwieldy task to develop and maintain knowledge bases for language interpretation. A natural language system should have models for the requirements of the user in addition to vocabulary and syntax (Winograd 1980). Domain knowledge is useful in orientating and focusing attention so as to derive a more compact representation and improve the efficiency of language processing.

Usability perspective

- It is insufficient for an NLI system to only understand well-formed natural language text. Given the fact that users’ input in natural language may be ungrammatical or incomplete, the lack of robustness of an NLI system in handling cases exception to formal language rules would lead to low accuracy rates.
- It is challenging to make NLIs more user-friendly. They are designed for mass usability in the first place. Some efforts have been made to enhance them by implementing intelligent agents in the agent community. More work is needed on how to design NLIs
beyond natural language interaction and further improve the usability of NLI systems.

The three types of challenges are not isolated but interconnected, whose relationships are displayed in figure 3. Knowledge support is the core to addressing all of the challenges. If sufficient and necessary knowledge about the world and the context of NLI interaction could be represented, we would overcome the technical challenges such as language ambiguity and variations. Accordingly, as natural language technologies become more mature and robust, the usability of NLI systems would be improved. Given the challenges facing the state-of-the-art NLI, we propose principles for NLI design as a solution to improve its usability and even its adoption.

3.2 General principles for NLI design

An NLI can be built by choosing from a large number of possibilities. As a result, there is no effective universal NLI for all applications. Drawing on relevant literature (e.g. Zoltan-Ford 1991, Nielsen and Mack 1994, Dix et al. 1998, Zadrozny et al. 2000, Brennan 1990) and our experience with NLIs, we develop general principles for NLIs design. The underlying rationale is to reduce the technical difficulty in developing an NLI system and to improve its usability by advancing the system’s knowledge about the language, the user and the interaction environment. The general principles consist of 8 Cs: clearness, conciseness, conversation, contextualisation, consistency, confirmation, clarification and customisation.

- **Clearness.** Although freedom for input allows many syntactic structures and many words for the same desired system response, user input is supposed to be non-ambiguous, clear and relevant to tasks in hand. Curtailing the variety in input may maximise the probability that an NLI system will understand each input correctly.
- **Conciseness.** Design system output with concise phrases by basing on fairly simple and somewhat related vocabulary. When the principle is applied to non-threatening error messages, it means that the messages should reiterate vocabulary and phrases that are understandable.
- **Conversation.** Treat language as a conversation, but not as disembodied grammatical sentences composed of strings of characters. This can be achieved in an NLI by preserving the parallelism (e.g. in words) in preparing answers to users’ questions, being informative in its response about what kind of conversational partner it is.
- **Contextualisation.** Define extensive discourse models, which in turn provide improved models of context-aware NLIs and personalisation. Improved discourse models can enable better one-on-one context for each NLI interaction. Discourse models are especially crucial to natural language dialog systems.
- **Consistency.** Consistently worded output of an NLI system not only gives users a sense of familiarity, but also encourage users to model the output. A consistent pattern in user input would in turn simplify the task of the NLI.
- **Confirmation.** Confirm requests with users before taking critical actions. For example, before permanently removing information from a system, the system should confirm that the user no longer wants that information.
- **Clarification.** Engage in a clarification dialog if an NLI does not understand a user. A good NLI should make clear to the user the functions available and provide informative feedback where necessary. Clarification can minimise misunderstanding of an NLI system about a user’s request, maintain the user’s trust and ultimately provide a correct response to the user.
- **Customisation.** Learn user models for an NLI system to adapt its components and system’s response to individual users. After a user expresses his/her interests, wishes and queries explicitly or implicitly by speaking, typing and pointing, an NLI system could automatically create a model for the user. The user model is used to customise the NLI for each user based on his/her culture-specific, user-specific and style-specific patterns. The customisation should be a continuous and evolving process.

Among the eight principles, the first 4 Cs are designed mainly to reduce technical difficulties, while the last 4 Cs
are designed primarily to improve the usability of an NLI system. All of them underscore acquiring additional knowledge to reduce uncertainty in generating an NLI. There is usually a trade-off between intelligence and reliability. In some contexts, users are unwilling to trade reliable and predictable interfaces for intelligent but unreliable ones. Therefore, NLI systems should provide some graceful exit mechanisms such as clarification and confirmation. We focus on naïve users in the above design. To cater to experienced users, the system can provide alternative means such as command-based interfaces to speed up the interaction.

4. NLI for information management on mobile devices

Mobile devices come in many forms. In this paper, we use mobile devices to refer to a narrow range of devices that are handheld and empowered by mobile computing and wireless communication technologies. Mobile devices such as personal digital assistants (PDAs) and smart phones allow people to access information and services at the right place at the right time. They are emerging as an alternative platform for information management. However, managing information with mobile devices faces major challenges from both sides:

- **Mobile handheld devices specific issues.** Compared with workstations, mobile devices have limited screen display, poor network connectivity, customer apathy, and so on (Samaras 2002, Sarker and Wells 2003). The small screen of mobile devices not only forces system designers and developers to selectively present information on the screen, but also creates significant inconvenience to user input and navigation.

- **Information management-related issues.** Information management applications require structured input, while the need for managing information is mostly for spur-of-the-moment situations and requires quick memory of notable information, preferably in free-formed notes (Campbell and Maglio 2003). The mismatch between the user’s need, the available support and the possible delay in transforming the information from free text into the required formats brings about the risk of losing information after a while.

As more and more people depend on mobile devices to manage their information, there is an emerging issue of how to better support users in information management on mobile devices. The analysis of NLIs suggests that users can benefit from them in improving the efficiency and effectiveness of information management on mobile devices. For example, navigating to the right application and inserting the information into the right slot in the application consumes a significant percentage of the user’s time. An NLI portal to information management applications may help the user to automatically locate the right application and update information in the right place. The economy in space usage of NLIs is very desirable to mobile devices. The learning ability of NLIs bodes well for a better interface over time. Requirement analysis of information management, as conducted in the next section, further sheds light on the potential of NLIs.

4.1 Requirements of NLIs for information management

All aspects of information management must be grounded in an understanding of requirements or needs of users of information systems. In this section, we begin with the special needs of supporting information management on mobile devices, and then translate them into user requirements for designing an NLI system.

Calendars, to-dos and contacts are examples of durable information management support. They tend to be well organised, designed to manage long-term activities and have archival value (Lutters 2004). These applications provide slot-based input described with a rich set of attributes. In order to input information, users typically have to look through a lengthy list of attribute slots one at a time by scrolling up and down the screen. As stated before, mobile devices are weak in supporting user navigation. Consequently, information management requires reducing the frequency of user navigation on mobile devices.

The problem with navigation goes beyond the scope of individual information management applications. In the current paradigm for information management, users must first select the right application and orient themselves to the interfaces of various applications. Such a practice entails additional navigation effort of users. Automatic classification of input information can save users’ effort and time in managing information with mobile devices. The requirement is substantiated with findings from the user interviews (Campbell and Maglio 2003) that users expect the systems to support automatic information classification and intelligent input methods.

To allow for quick memory of notable information, free-formed ubiquitous microneotes come into play. Microneotes (Campbell and Maglio 2003) capture notable information such as to-do lists, phone numbers, dental appointments, street addresses, brilliant ideas and anniversary dates. They usually serve as temporal memory storage, which faces the risk of getting lost after a while. In order to turn the microneotes into prospective memory, users need to subsequently transform them into structured forms specified by corresponding information management applications. Thus, it is desirable for an information management
application to be able to process free texts and to extract structured attributes from the text.

The functions of different information management applications are not exclusive, but have overlaps. For example, a memo could be a calendar item such as a scheduled appointment/event or an entry of contact information. In fact, users sometimes are not sure which application to choose and demand creating linkages between different applications (Campbell and Maglio 2003). Therefore, different applications should be connected via a uniformed interface, enabling information linkage and integration across applications.

The state of how the current electronic technology and classic paper-based tools are used to manage to-do lists, appointments and other types of notable information suggests that mobile devices would be a good candidate if enhancements can be made to reduce time on entering new information and other aspects. We take the first step towards enhancing the usability of mobile devices by analysing the requirements of information management on mobile devices, including minimisation of user navigation, automatic information classification and intelligent input methods, textual information extraction and processing, and a uniformed interface to link different applications. To this end, NLIs, along with other techniques, presents a promising solution by narrowing the gap between complex human language and diverse information management applications. Zadrozny et al. (2000) argue that there is no effective universal interaction without natural language dialogue. In the next section, we propose architecture of an NLI-enabled information management system.

4.2 System architecture

According to the principles for NLI design and requirements of information management on mobile devices, we design the architecture of an NLI-enabled information management system, as shown in figure 4. The key components are an NLI scratch pad, natural language processing, case-based reasoning, application controller and clarification/confirmation tailored to user preferences. Functions of each component in the architecture are briefly described as follows:

4.2.1 NLI scratch pad. The scratch pad provides an easy-to-use and unified interface for managing notable information. This is the default entry screen serving as a scratch pad. The interface can accept text and even speech input in natural language, which frees users from choosing particular applications and attribute slots via navigation.

4.2.2 Natural language processing. The natural language processing component is the essence of the entire system. It is responsible for parsing free-text input, identifying relationships between different phrases in the text and extracting specific types of information from the text. For example, given the input, ‘meet Tom at 2pm’, the language parsing tool recognises ‘2pm’ as a point of time and ‘Tom’ as a person’s name. With the support of dictionaries and knowledge bases in natural language processing, users are not bound to fixed words and phrases in their input. The semantic dictionaries help the NLI system to identify semantic similarities between different words and phrases in order to initiate the right action. For example, to edit a contact item, one may use any of the following words: change, alter, append, correct, replace, rewrite, and so forth.

4.2.3 Case-based reasoning. This component is responsible for predicting user’s intent from the parsed natural language input. User’s intent consists of two parts: select an information management application and take a specific action in that application. Based on the language patterns observed from users’ input and the possible overlaps between the information in different applications, case-based reasoning (Han and Kamber 2001) is selected to predict user’s intent. For example, the majority of user requests are aimed to update, delete, insert, or display information. A case-based classifier is built on a library of past cases. The case base records both user input and system response (with respect to both application and action decisions). Given a new input, a case-based classifier first checks whether an identical request exists. If a match is found, the application and action corresponding to that request is returned. Otherwise, the classifier tried to map the new request to segments of more than one existing case based on syntactic, semantic

Figure 4. The architecture of an NLI-enabled information management system.
and discourse similarities. Viewing the old cases as the neighbour of the new request, the case-based classifier tries to combine the solution of the neighbouring training cases in order to propose a solution for the new request. If no close neighbour can be found, the new case would be incorporated into the case base and used for further reasoning. As such the classification performance of the case-based system would be increased over time. Case-based reasoning can also support the personalisation of NLI systems by nature.

4.2.4 Confirmation/Clarification. Feedback is critical to the success of the interaction. This is especially true given that natural language processing is prone to errors and misunderstandings, which can cause the wrong action to be taken by the system (Lai et al. 2002). To avoid unintentional ‘catastrophic’ action, especially for a novice user, the system provides the option to confirm an action before any change really takes place. For example, the system can confirm with the user before deleting a phone number from contact. In case an input is misunderstood, the user could choose to cancel the operation and instruct the NLI system to take the right action. When the system is uncertain about the user’s intent in input, it would follow up with a clarification dialog.

4.2.5 Application Controller. Application controller connects various information management applications uniformly, which allows both information exchange and information integration across applications. The controller is interfaced with information bases (i.e. long-term memory aids), which are the back end of information management applications. Motivated by the interoperability advantage and extension potential of semi-structured XML notations, XML is selected to represent information bases. Moreover, XPath (Clark and DeRose 1999) and XQuery (Boag et al. 2003) serve as the communication protocol between the application controller and the information bases. As a result, appropriate action will be taken in response to the user’s intent. Finally, the execution status will be reported back to the user.

There are other components that may be incorporated into the NLI-enabled architecture, which are beyond the scope of this research. For example, an NLI system can take proactive action to alert users when some information remains unused for a long time or if there is any conflict between the new input and existing information. Maintenance is very important to enhancing the efficiency and effectiveness of a system. For example, the case base will be purged periodically to make cases more representative and parsimonious. The application controller supports generating summary responses from multiple applications. In addition to the NLI system – serving as an abstract layer between a user’s input and information management applications – users still have the option to enter data on mobile devices in the traditional menu-based way.

4.3 Usage scenarios

4.3.1 Scenario 1: Information retrieval. User input:

Show schedule for Tuesdays of this month.

The system identifies the part-of-speech of each word and determines the phrase structures and semantic relationships in the input. For example, it recognises both ‘Tuesday’ and ‘this month’ as noun phrases indicating the time, which are combined to form a higher-level noun phrase. It then converts ‘this month’ into an actual month from the system date. The parsed input is then matched against the case bases, and the case of an old request, ‘Display my schedule for today’, is selected as the closest neighbour. Since the matched case is a calendar request, the system infers that the user is intended to access the calendar. The similarity between ‘show’ and ‘display’ suggests that the user requests for a display action. Based on the matched case, the system generates a query in XQuery and XPath and sends it to the information base of calendar. Finally, the schedules for all Tuesdays of the current month are presented to the user.

4.3.2 Scenario 2: Information update. User Input:

Change Marge White’s phone no to (410)4558888.

The natural language processing component parses the input and recognises ‘Marge White’ as a name and ‘(410)4558888’ as a phone number. It is then inferred from matched cases that the input is an update request to contact application. The name and phone number are extracted from the input to form an update query to the information bases of contact. In view that the same names may be written in variant forms, approximate matching rather than accurate matching is desirable in searching for an existing name. A confirmation dialog follows to confirm the name matching before the change takes effect.

It is illustrated from the above usage scenarios that the NLI-enabled architecture eases users’ effort in interacting with mobile devices for information management.

5. Conclusion and future directions

NLIs allow humans to communicate with computers in a fashion that resembles natural human-to-human language (Petrick 1976). NLI systems built so far have primarily focused on addressing the problem of information access in
conventional database systems. We extend the application of NLIs to support an emergent need for managing information on mobile devices.

We made multifold contributions to the research community in this study. First, we analysed benefits and challenges of developing NLIs and elicit user requirements for managing notable information on mobile devices. Second, we proposed general principles for NLI design for mobile devices, which fills in a gap in the current literature. Third, to meet the requirements for information management on mobile devices, we innovatively designed NLI-enabled information management architecture. The architecture supports reducing users’ navigation effort and improving the efficiency and effectiveness of managing information on mobile devices. The former overcomes a major limitation of mobile devices, and the latter enhances the usability of existing information management applications. Moreover, the XML-based approach to information representation enables information integration across different applications.

We should never underestimate the challenges of developing a satisfactory NLI and anticipate both competence and performance errors (Thompson and Ross 1987). There are a variety of causes for this. First and foremost, natural language involves several levels of ambiguity: lexical, syntactic, semantic and pragmatic. Second, dealing with subtlety in user’s requests is challenging (Lai et al. 2002), who actually have difficulty in formulating precise and unambiguous requests in English. The ambiguity and subtlety are preventing NLIs from being consistent and reliable because of possible errors. Furthermore, it is difficult to capture domain and context knowledge that can help with disambiguation.

We propose solutions to address the above challenges of NLIs in this paper. We hope that it will inspire more research and application of NLIs on mobile devices. The architecture and scenarios exhibit the ideas underlying NLIs and ensure a basic capability that can be demonstrated immediately, but capability extensions are needed in the following areas. First, empirically test the usability of the NLI system for information management on mobile devices. Second, extend the NLI system to support speech modality and integrate the NLI with other types of input methods. Third, address semantic heterogeneity between the NLI system and legacy systems. Finally, in addition to the pull model initiated by users, the need for information management can be pushed to users by an NLI-enabled system. This will pave the way to developing intelligent personal agents.

The pragmatic goal of natural language and multimodal interfaces is to enable ease-of-use for users in performing more sophisticated and intelligent human–computer interactions (Zadrożyń et al. 2000). NLIs will continue to improve as more of the technology problems are solved.

NLIs, as introduced in this paper, can be extended to other applications on mobile devices as well as information management applications on PCs.

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