Adding Semantic Web Knowledge to Intelligent Personal Assistant Agents

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Abstract. Intelligent Personal Assistant (IPA) agents are software agents which assist users in performing specific tasks. They should be able to communicate, cooperate, discuss, and guide people. This paper presents a proposal to add Semantic Web Knowledge to IPA agents. In our solution, the IPA agent has a modular knowledge organization composed by four differentiated areas: (i) the rational area, which adds semantic web knowledge, (ii) the association area, which simplifies building appropriate responses, (iii) the commonsense area, which provides commonsense responses, and (iv) the behavioral area, which allows IPA agents to show empathy. Our main objective is to create more intelligent and more human alike IPA agents, enhancing the current abilities that these software agents provide.

Key words: Intelligent Personal Assistant Agents, Semantic repositories, Subject-centric computing

1 Introduction

The amount of information available is growing exponentially. As a result, people can be overwhelmed by the information published in a plethora of new books, web pages, etc. In addition, advances in information technology have reduced the barriers in electronic publishing and distribution of information over networks anywhere in the world, increasing the number of publications [1]. To address the problem of information overload and to convert all available information sources in useful information, Intelligent Personal Assistant (IPA) agents have emerged as a feasible solution to assist users in different application domains.

Intelligent Agents (IAs) are autonomous entities provided with an initial knowledge and with the capability of learning to achieve their goals [2]. The functionality of IAs covers several attributes, including autonomy, continuity, adaptability, goal orientation, communication, and learning ability which gives intelligence to the agent. By learning, it becomes able to adapt itself to its dynamic environment, reducing work and information overload. The software agents approach is a key area in the field of Artificial Intelligence research.

IPA agents are software agents which assist users in performing specific tasks. They should be able to communicate, cooperate, discuss, and guide people. One significant difference between IPA agents and IAs is that IPAs collaborate with the user in different ways, and in virtually unlimited tasks and applications, by hiding the complexity of difficult tasks, performing tasks on behalf of the user, and teaching the user to monitor events and procedures [3]. We think that IPA agents not only have to continuously improve their behavior based on similar previous experiences (as recommender agents usually do), but also they should demonstrate competence to the user while simultaneously developing social relationships to engage him.

Semantic repositories are data engines similar to the DataBase Management Systems (DBMS) which allow for storage, querying, and management of structured data. Unlike DBMS, they use ontologies as semantic schemata. This allows them to automatically reason about the information. Semantic repositories potentially offer easier integration of diverse data and more analytical power. Over the last decade, the Semantic Web emerged as an area where the semantic repositories become very important [4, 5]. The Semantic Web effort aims to make such knowledge accessible to computer programs by encoding it on the web in machine interpretable form [6].

In this paper we present a novel approach to enhance the IPA agents with semantic knowledge. These IPA agents will be provided with knowledge based on semantic repositories, aiming to support people in some different issues or scenarios. Our proposal may bring great benefits in computer-aided guiding.

This paper is organized as follows: Section 2 describes the related work with regard to several techniques applied to provide intelligence to IPAs, and their different applications found in the literature. In Section 3 we introduce the different problems that motivated our work. Section 4 details our proposed architecture. Finally, Section 5 presents some concluding remarks.

2 Related Work

In the literature we can find several works addressing IPA agents. We have divided these works into two different subsections: (i) works which proposed different techniques to provide intelligence to IPA agents, and (ii) works which proposed different applications for them.

2.1 Techniques to Provide Intelligence to IPA agents

The majority of the techniques proposed to provide intelligence to IPA agents are based on three different knowledge representation approaches: (i) conceptual graphs, (ii) ontologies, and (iii) neural networks.

Zhang et al. [7] proposed an intelligent information retrieval model based on the multi-agent paradigm and Conceptual Graphs (CGs). The CG, developed by Sowa [8], is a knowledge representation language initially designed to capture the meaning of natural language. The system represents queries and documents in CGs, which brings semantic in some functions, such as intelligent search, auto-notification, navigation guide, and personal information management.

Ontologies have become a very powerful tool of representing the information and its semantics. For example, Lee et al. developed OIDSA [9], an ontology-based decision support system agent designed to project monitoring and control of Capability Maturity Model Integration (CMMI). More recently, Chen et al. [10] explained how to provide a memory mechanism to IPA agents. This solution was inspired by a case memory model in the domain of Case-Based Reasoning (CBR) and helped by an ontology module to generate a new case. Wang et al. [11] proposed an intelligent healthy diet planning multi-agent (IHDPMA), including a personal profile agent, a nutrition facts analysis agent, a knowledge analysis agent, a discovery agent, a fuzzy inference agent, and a semantic generation agent for healthy diet planning. The IHDPMA provides a semantic analysis of healthy diet status for people based on the pre-constructed ontology by domain experts and results of fuzzy inference.

Semantic Neural Networks (SNNs) are generally used for natural language processing. Czibula et al. [3] presented an IPA agent that learns by supervision to assist users in performing specific tasks. For evaluating the performance of the agent a case study was considered, and a neural network was used by the agent to learn by supervision from its experience.

To the best of our knowledge, none of the previous works have studied how IPA agents would support users in their knowledge acquisition process when attempting to find information through semantic repositories.

2.2 Common Applications of IPA Agents

IPA agents have been applied in many applications and for a variety of purposes. The most common application has been filtering information in the Web through software agents specialized in tasks such as improving the information retrieval process, or supporting users through recommender systems. However, other different interesting applications can be found on the literature.

There are different purposes that IPAs can be applied to, such as hiding complexity of difficult tasks, performing tasks on behalf of the user, teaching the user, and monitoring procedures and events. Next, we present some interesting proposed IPA agents and their applications.

Ding et al. [12] presented an intelligent Personal Agent for Web Search (PAWS) designed to carry out personalized web search for each user based on his individual preferences. The PAWS intelligently utilizes a Self-Organizing Map (SOM) as the user's profile and therefore, is capable of providing a high quality answer set to the user. Fung et al. [13] presented two proposals to solve the problem of distributed search over the Internet. The first one is based on using an IPA agent to assist the user in the information retrieval process, and the second one treats distributed knowledge bases located at different servers as an integrated domain knowledge.

Homayounvala et al. [14] studied the evolution of personal assistant agents from when they were introduced and their applications in mobile telecommunications. In addition, a migration policy based on user classification was proposed to enhance the performance of mobile services.

In [15] authors presented iAPERAS, an expert system which uses Bayesian networks. This system is addressed to non-professional athletes which usually rely on the information about training methods and nutrition recommendations provided online. It represents a better alternative to online resources, because it is based on scientific research findings and evaluated by domain experts.

Regarding the use of IPAs in education (also known as Intelligent Pedagogical Agents), we can found several works. In [16] authors presented Adele, a pedagogical agent that is designed to work with Web-based educational simulations. The Adele architecture implements key pedagogical functions: presentation, student monitoring and feedback, probing questions, hints, and explanations. Wilges et al. [17] tested and verified a framework that aims to implement a set of resources for developing Intelligent Learning Objects. For this purpose, a learning environment model was created. The model has an Animated Pedagogical Agent (APA) that interacts with two specific agents of the system. In [18] authors presented the evolution description and relevance of Intelligent Virtual Teaching Environment (IVTE) and also gave emphasis in the Cognitive Agent Model represented by an Animated Pedagogical Agent. The purpose of IVTE software is to educate children to preserve the environment. The IVTE software was implemented with Multi-agent (MAS) and Intelligent Tutoring Systems (ITS) technology, which gives more adaptable information to the teaching process. The adaptable information is promoted by an Animated Pedagogical Agent which monitors, guides and individualizes the learning process using a student model and teaching strategies.

3 Motivation

In our work we aim to provide IPA agents with semantic web knowledge, making it possible to obtain more specialized assistants which can help users in different domains and scenarios. Our proposed system tries to address different applications such as helping elderly people and people with special needs, improving the education process (in formal or vocational learning), and helping drivers (in Intelligent Transportation Systems).

With an aging population, the number of individuals requiring long-term care is expected to dramatically increase in the next twenty years, placing an increasing burden on healthcare [19]. In addition, the elderly population in rural areas often faces a number of challenges in obtaining healthcare. Access is limited by distance and lack of transportation. Many rural patients are also socially isolated and often live some distance away from family members and friends. The use of IPA agents can provide support in terms of medical evaluation and intervention as well as social support with the intent of allowing patients to function in their home environments as long as possible (i.e. enhancing their quality of life).

Moreover, the Internet has opened up a range of new communication opportunities for people with special needs since it is an accessible communication medium that provides an opportunity to exchange practical information and support and to experience an accepting relationship with less prejudice [20].

The use of IPAs in education (also known as Intelligent Pedagogical Agents) provides benefits to the educational process [21]. IPAs can: (i) increase the students' engagement, (ii) add value by giving new educational possibilities and computational-richness support, (iii) improve the interactions between the computer and the learner, (iv) act as a teacher, learning facilitator, or even a student peer in collaborative settings, and (v) act pedagogically on behalf or with learners.

Regarding the car industry, in the past, people were focused on how to build efficient highways and roads. Over time, focus shifted to mechanical and automotive engineering, in the pursuit of building faster cars to surmount greater distances. Later on, electronics technology impacted the construction of cars, embedding them with sensors and advanced electronics, making cars more intelligent, sensitive and safe to drive on. Now, innovations made so far in wireless mobile communications and networking technologies are starting to impact cars, roads, and highways [22]. We foresee that IPA agents can also participate in the Next Generation Intelligent Transportation Systems (ITS), by helping the drivers and providing useful services, such as calculating efficient routes, save fuel, assist drivers in special situations, etc. The use of IPA agents in car industry, embedded in the car On-board Units (OBUs), will drastically change the way we view transportation systems of the next generation and the way we drive in the future.

In our proposal we aim to improve IPAs by enriching them with suitable semantic web knowledge, since semantic repositories provide them documentation of knowledge, intelligent decision support, self learning, commonsense, and reasoning abilities [23].

4 Our Proposal

In this section we present our proposal in detail, explaining the different knowledge areas that an IPA agent should have in order to facilitate and improve the knowledge acquisition process. In this work we are only interested in IPAs as knowledge consumers, instead of contributors. Figure 1 shows our proposed conceptual architecture. As shown, people can express a problem to the IPA agent about something of their interest, and it will provide them with a suitable answer. One important issue to be considered should be user modeling and understanding. Hence, user's parameters such as behavior, background knowledge, needs and preferences will be important for the IPA to contextualize its performance. Our IPA Agent has four differentiated areas: (i) the rational area, (ii) the association area, (iii) the commonsense area, and (iv) the behavioral area. In the next subsections we explain them further.

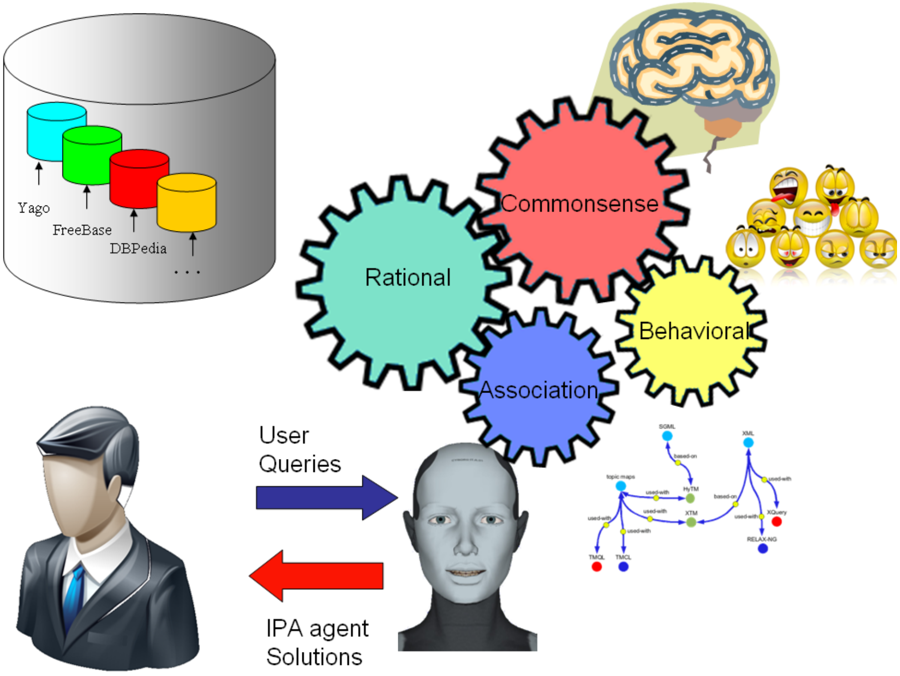

Fig. 1. Proposed conceptual architecture.

When someone states a question or a problem, the IPA agent processes it, and performs different tasks: it searches in a Commonsense Knowledge Base, also in different Knowledge Bases, and tries to find the most appropriate emotion in this context. These tasks can be done in parallel, reducing its response time. Once it has obtained the results, it makes the associations and builds the correct answer. In order to increase the level of realism, the interaction with people could be done with voice.

4.1 Rational Area

Our main objective is to provide IPA agents with Semantic Web Knowledge, so this is one of the most important areas. The IPA agent will consult some different semantic web repositories to obtain the most suitable contents regarding the user's needs. We have decided to use semantic repositories with the aim of enhancing IPA agents by providing them with automatic data reasoning capabilities, and achieving interoperability between those repositories. As previously mentioned, this system allows parallel search in different repositories, thus reducing the response time. Moreover, this design presents high scalability since new metadata schemata can be easily integrated.

Table 1 shows some of the possible knowledge repositories that our IPA agent could integrate. Depending on the selected application addressed by the IPA, more specific knowledge databases could be added to the system, or other important information will be required. For example, in Intelligent Transportation Systems, the location of the car obtained thanks to the Global Positioning System (GPS) and roadmaps, is also necessary for semantic navigation purposes. Regarding applications related to elderly people or people with special needs, indoor navigation is also important. For example, in hospitals where both the working staff and patients need to find and use the "best" semantic navigation path [24].

Table 1. Characteristics of some Semantic Repositories

Name	**Description**
YAGO [25]	YAGO is a huge semantic knowledge base. Currently, YAGO knows more than 2 million entities and 20 million facts about these entities. Unlike many other automatically assembled knowledge bases, YAGO has a manually confirmed accuracy of 95%.
DBPedia [26]	DBpedia is a community effort to extract structured information from Wikipedia and to make this information available on the Web. DBpedia allows users to ask sophisticated queries against Wikipedia, and to link other data sets on the Web to Wikipedia data. The DBpedia knowledge base currently describes more than 3.4 million things, out of which 1.5 million are classified in a consistent Ontology.
FreeBase[1]	Freebase is an open, Creative Commons licensed repository of structured data of more than 12 million entities. Freebase is also a community of thousands of people, working together to improve Freebase's data.
MERLOT[2]	MERLOT is a free and open online community of resources designed primarily for faculty, staff and students of higher education from around the world to share their learning materials and pedagogy. The MERLOT repository includes learning materials, but assignments, comments, personal collections and Content Builder web pages. The learning materials are categorized into 14 different types.

4.2 Association Area

This area will merge the results obtained in the Rational Area, making the appropriate associations and decision-making. The objective is to make the IPA capable of making skillful intellectual tasks since it will be enhanced with knowledge provided by semantic repositories.

[1] http://www.freebase.com/
[2] http://www.merlot.org/

The traditional information organization has been always focused on documents, folders, and files. However, the Semantic Web which adds modular, and reusable knowledge resources, is difficult to comprehend by the end user due to the complex structure of knowledge contained in semantic repositories. Humans do not usually look for a certain document or folder, instead they look for information about a particular subject that they are interested in. According to this, we suggest for this area a subject-centric approach, in which information should be organized by subjects, as users typically think.

To implement this area we planned to use a context-aware adaptive system which can tailor its behavior depending on the different user requirements in every moment. The different knowledge resources managed by the IPA agent (i.e., Semantic Repositories, and the Commonsense Knowledge Base) can be searched in parallel, but the results must be correctly merged to obtain the most suitable answer depending on the context. In this way, the IPA agent could assign different weights to the available results obtained from the knowledge resources.

In the future we want to test some state-of-the-art Artificial Intelligence algorithms to find the most suitable to be used by IPA agents for multiple purposes. Therefore, we argue that our proposal can be used in quite different scenarios, such as computer-aided learning, supporting elderly people, people with special needs, formal and vocational education, or in Intelligent Transportation Systems.

4.3 Commonsense Area

As previously mentioned, our IPA will be provided with semantic repositories. Since the resources offered by semantic repositories are commonly limited to formal taxonomic relations or dictionary definitions of lexical items, we think that our system should also integrate commonsense knowledge (i.e., the collection of facts and information that an ordinary person is expected to know).

Thanks to this area, the IPA agent will be provided with Commonsense Knowledge. This area will help to analyze and process both the input queries, and the output responses. It will also support the behavioral area to find the most appropriate emotion according to the context. To accomplish this, a resource which captures a wide range of commonsense concepts and relations, and allows commonsense inferences should be integrated. Table 2 shows a comparison of two open Commonsense Knowledge initiatives which could be used in our system.

Table 2. Comparison of two open Commonsense Knowledge initiatives

	OpenCyc [27]	**ConceptNet [28]**
Generation	Largely handcrafted	Automatically from OMCS Corpus
Acquisition	Knowledge Engineers	General Public
Reasoning	Formalized Logical	Contextual Commonsense
Content	Mapping text	Real-world texts

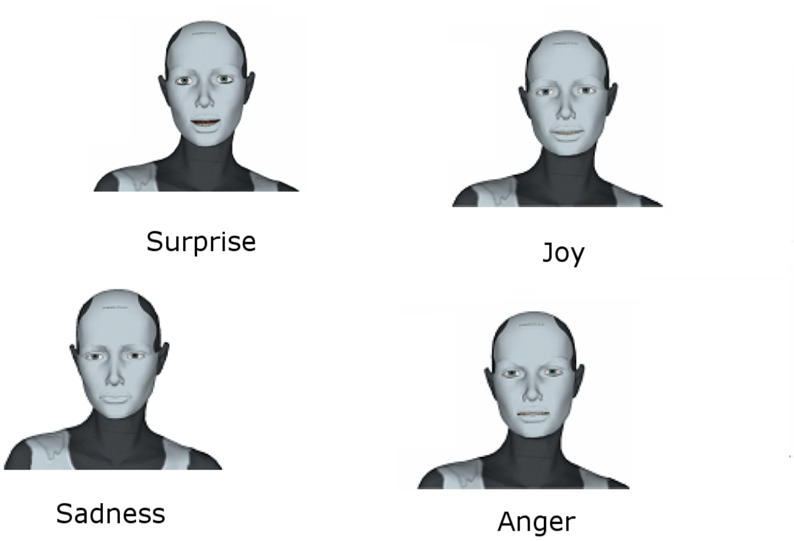

Fig. 2. Example of emotions that would be expressed by IPA agents [29].

4.4 Behavioral Area

An important issue in developing personal assistants is emotion [30–32]. An IPA agent can better assist users with an appropriate usage of several emotions. This area will make it possible to increase the level of realism of the assistant agent, addressing some of the key drawbacks that the majority of IPA agents (i.e., the lack of realism, emotions, personality and social interactions). Behavioral area should cover facial expressions as well as body language, or more general non-verbal communication, but also interaction patterns with the learners, etc. The IPA agent will react according to the context and the sense of the queries made by users, including facial and vocal expressions of emotion.

The relationship with a user should affect the emotional reactions of the assistant agent, and its emotional status and mood must be updated with emotional impulses from the environment [33]. For example if the user is saying something bad happened to him and the IPA agent has positive impressions of the person, the resulting emotion will be sorry for this situation.

Generally, agents exploit two different channels to show their emotions: Visual and aural channel [34]. Before exhibiting an emotion, the agent has to "feel" something, and then he can show his feeling using the aforementioned channels. A pedagogical agent may feel excitement and joy when the learner does well and he can be disappointed when problem-solving progress is less than optimal. Eliciting emotions is a much more difficult concern than conveying emotions. For this purpose, the agent has to recognize the facial expression as well as gesture and speech of the user. Figure 2 depicts some emotions that should be expressed by IPA agents.

5 Conclusions

In this paper we present a proposal to add semantic web knowledge to IPA agents. Our proposed assistant agent does not simply give out information, it also provides guidance for the user, and demonstrates competence while simultaneously developing a social relationship to motivate him. Our main objective is to create more intelligent and more human alike IPA agents, enhancing the knowledge acquisition process of people.

We believe that integrating an autonomous IPA agent merging suitable semantic repositories could mitigate some problems detected in current systems, since it will increase the level of realism, reaching a level of interaction similar to face-to-face. Assistant agents will also provide intelligent support and guidance to mitigate the "infoglut" (i.e., when a person is overwhelmed by the presence of too much information).

Shifting the information architecture to a subject-centric perspective, means: (i) changing the way that software and interfaces are designed, (ii) deciding whether or not two different objects represent the same subject, and (iii) empowering a new level of interactivity between systems at global scale [35].

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