

Insights into the Design of Middle Agent Architectures: The Case of Multi-Agent Information Extraction

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Introduction This paper describes our work on the acquisition of extraction patterns for an Information Extraction problem. In particular, we introduce a multi-agent architecture, identifying several possible middle agents, to allow agents representing users with similar interests to share knowledge. This research provides general insights into the value of user profiling, intelligent filtering and social responsibility, all of which may be important in e-commerce applications.

Information Extraction Information Extraction (IE) is a Natural Language Understanding field concerned with extracting relevant information about the relationships between entities and objects within a text corpus. One of the benefits a user may see by using an IE system would be the time saved in reading through a large text corpus, and identifying the complex relationships between the entities found in the texts.

For a query on a domain of interest, an IE system requires the user to define a representation of knowledge within the domain, such as an ontology, and a collection of extraction pattern rules, sometimes referred to as a dictionary of extraction patterns, which help identify key words or phrases within text. Unfortunately, many IE applications require a large amount of training to derive a sufficient base of extraction patterns to retrieve information with a relatively high performance. If important key words or phrases are not identified, and do not generate a relevant extraction pattern, then this extraction information will be overlooked in future documents. These approaches still require a user to determine the training corpus, and do not make use of the expert knowledge that similar users may be willing to provide.

Our Multi-Agent Proposition Our approach uses a multi-agent architecture to facilitate the sharing of extraction patterns (see Figure 1). This multi-agent community is mainly composed of agents that represent users. Each agent has a complex user profile, information about the multiple domains of knowledge that interest the user, and the extraction patterns that were learned either through normal training activities, or through knowledge acquired from other user agents.

These agents can be called upon to assist a user who wants help in deriving extraction patterns.

Our proposed multi-agent community also includes a set of middle agents, which help a user agent search for potential agent candidates who may be able to satisfy the information request. In addition, these middle-agents participate in negotiating the desired knowledge from other agents in the community. General information about middle agents is available from (Decker, Sycara, & Williamson 1997), and more specific information on matchmaker and brokering middle agents is available from (Sycara, Lu, & Klusch 1998).

Assumptions:

- User agents, which can provide extraction patterns within this multi-agent environment, have registered their location and capabilities to the Middle Agent M .
- A User Agent U , would like to ask a query Q to an Information Extraction system, but has decided to acquire information from the multi-agent environment.

General Approach:

1. U formulates an Information Request R based on query Q . R contains user-profile information on the domain, such as user preferences, domain ontology, agent preferences.
2. U sends the Information Request R to the Middle Agent M .
3. Middle Agent M decodes the message, and uses user preference information to help eliminate or favor particular agents in the community. M uses R and the advertised capabilities of the agents in the community to derive a candidate (ordered) set of agents S , which are believed to be able to provide extraction patterns to satisfy R .
4. Based on the type of Middle Agent M , there are different interaction protocols that are used to derive information about the domain.
 - Centralized approach to agent communication (Middle Agent M is a Broker or Blackboard Agent)
 - Non-centralized approach to agent communication (Middle Agent M is a Matchmaker or Introducer Agent)
5. After the User Agent U has acquired extraction patterns from the agent community S , it presents the user the extraction patterns for review, using an intelligent configurable filter to avoid repeating already accepted extraction patterns, and previously rejected extraction patterns. The user updates her dictionary of extraction patterns.
6. If necessary, the User Agent U should update its domain knowledge (ontology) then proceed to re-register its updated capabilities with Middle Agent M .
7. The user proceeds to perform regular Information Extraction to answer Query Q with its dictionary of extraction patterns.

Figure 1: High-level algorithm for our extraction pattern acquisition strategy using middle agents in a multi-agent community

Fundamentally, middle agents must have the capa-

bility to accept advertisements from user agents, which define the user's knowledge over multiple domains of interest, and capabilities to provide knowledge. When a user discovers that she lacks sufficient knowledge about a particular domain, she can ask her user agent to construct an information request containing detailed information about the domain of knowledge and some of the user's knowledge acquisition preferences. Middle agents accept such information requests, then are primarily responsible for utilizing previously advertised user agent capabilities to recognize which agents can provide the desired knowledge by sharing extraction patterns.

The different types of middle agents available will help determine the communications protocols that should be used to facilitate the acquisition of knowledge, as follows. With a **Broker** the middle agent facilitates the complete exchange of extraction patterns privately, such that the agent requesting the information does not know anything about the agents providing the information and vice-versa. With a **Blackboard** the middle agent maintains a blackboard, similar to the idea of a newsgroup, where information requests are posted, and agents can post sets of extraction patterns onto the blackboard to satisfy a request for information. User agents can search the blackboard; hence previous queries and their respective answers may be quickly accessible for future users with similar information needs. With a **Matchmaker** the user agent who formulated the information request receives a list of candidate agents from the middle agent. The user agent initiates communications with this set of agents which are believed to be capable of satisfying the original information request. With an **Introducer** the middle agent sends several messages to the candidate set of agents who are believed to be able to satisfy the original information request. These agents may choose to initiate communication, and exchange knowledge with the user agent who requested the help of others agents, in order to acquire extraction patterns for completing an Information Extraction task.

User Modeling and Social Responsibility How should domain knowledge be represented, and what level of detail should be considered when developing a user profile? In our model, the user profile is composed of a set of ontologies representing the knowledge the user has about several domains of interest, a set of user preferences that are defined with respect to each domain, and the dictionary of extraction patterns that are associated with each domain.

Currently, a user can define user preferences for: managing the filtering and visualization of rejected extraction patterns; specifying which agents in the community she feels are reliable; and defining acceptable communication time-limits.

The user profile information also affects the level of detail included in the data structures used to represent the extraction pattern objects in the dictionary. For instance, to allow a user to indicate a preference

for certain types of intelligent filtering in the user profile, extraction pattern objects need to be augmented to include information pertaining to their creation and exchange in the multi-agent environment. This information could take the form of a time stamp to indicate when the extraction pattern was received, or include information indicating which agents were responsible for generating the extraction pattern.

In a community of agents sharing resources, such as knowledge in the form of extraction patterns, some assumptions about the social responsibility of agents should also be considered to ensure the success of the community. Trust is an important issue in any relationship and should be a concern when acquiring knowledge from another user agent. Users should be able to access the information that is retrieved from another user, and decide whether to accept or reject these extraction patterns. A user should be able to change her perception of agents by avoiding or choosing not to consult particular agents in future requests for help.

A community of agents sharing knowledge, no matter how large, can suffer from lack of information due to the general laziness of the community. If no user initially exerts some effort in training and deriving extraction patterns for any domain, then no extraction patterns will exist in the agent community.

Insights for E-Commerce The position taken in this paper is that AI researchers examining e-commerce would benefit by learning how we handle middle agent architectures in our application area of information extraction. Moreover, our proposed method of sharing extraction pattern knowledge could be a useful model for researchers who are trying to develop societies of agents for their tasks. In particular, an approach to electronic commerce which uses brokering and match-making service should strongly consider intelligent filtering of messages received from a community of agents, and allowing user agents to represent user preferences towards other agents in the community. We are also very interested in improving our current model, to consider the impact of knowledge acquisition when information is available for a price, rather than for free.

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