Using Relational Concept Knowledge to Improve Search in Referral Networks (Extended Abstract)

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ABSTRACT
The notion of referral networks, as presented in the work of Singh and Yolum, and their application to knowledge management, lacks two fundamental aspects; the relation of concepts within a domain, and the ability of an agent to dynamically change their interests based on suggestions in the form of concept relations. This paper introduces the concept of an oracle agent, which is an agent with relational concept knowledge that can supply suggestions to a querying agent on how to adapt their interests. These new features allow agents to search in new ways so as to achieve superior results and as a consequence outperform agents in a traditional referral network.

Categories and Subject Descriptors
I.2.11 [**Distributed Artificial Intelligence**]: Intelligent Agents, Multi-agent systems.

General Terms
Algorithms, Experimentation.

Keywords
Social/Management Science, Social/Organization: Groups and Teams.

1. INTRODUCTION
This paper builds on top of the existing work in the field of Referral Networks [1], [3], [4] by extending how knowledge is maintained and modelled in those networks. The objective is to study the effect of relational concept knowledge on the quality, efficiency and authoritativeness of a referral system. Thus, how agents within a referral network with concept knowledge assist other agents in finding useful knowledge via suggestions is examined and several learning algorithms are proposed for concept propagation, learning, and evaluation. Additionally, localized concept knowledge trust is modelled using a localized trust automaton (not described here) to aid in minimizing risk of using useless or malicious pieces of concept knowledge. The notion of agent health is also introduced as a reinforcement technique to drive evaluation of concept knowledge.

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2. EXTENDED REFERRAL NETWORKS

2.1 Referral Networks: An Overview
Expertise, interest and sociability within a referral network are represented using the Vector Space Model [2]. For a description of Referral Networks, the reader should consult [1], [3], [4].

2.2 Relational Concepts
Extended referral networks function by introducing concept relations and allowing them to propagate through the network. Concept knowledge is contained within oracle agents. Concept relations are modelled by two numbers representing the indexes within the VSM that are related. The concepts are unidirectional.

Data Structure 1: Concept-Relation

```
1:  int domainA;
2:  int domainB;
3:  Agent suggestingAgent;
```

2.3 Simulation Algorithms
The following changes to the basic algorithms for a referral network are made. First, when an agent receives answers to a question it integrates concepts that are returned to it into a concept knowledge store. Second, when an agent answers a question it provides concept relations if it has such knowledge along with any answers or referrals. Health is introduced in order to assess the utility of the concept relations provided.

2.4 Health
The purpose of health in a referral network is twofold: Perpetuate a reinforcement learning cycle which causes the agent to eventually adapt interests in a useful way and provide the basis for a utility metric which drives trust in other agents.

The health of an agent is modelled as the absolute difference between its current expertise vector and some target expertise vector, which is given by the human operator at the start of the simulation. The target expertise vector is essentially a "yard-stick" measure of how well an agent is learning intended concepts. As the agent learns more related concepts the health of the agent will move towards zero, indicating that it has learned all needed concepts.

2.5 Suggestion and Interest Adaptation Policy
With the introduction of concept relations, two new policies need to be introduced: suggestion policy and interest adaptation policy.

2.5.1 Suggestion Policy

Within the referral network simulator the suggestion policy is used when an agent is asked a question.

ALGORITHM 1: hasAGoodSuggestion(Query Q_i)

```
1:  largestIndex = index in Qi with largest value
2:  Loop through all concept relations in set
3:    conceptRel = current concept
4:    indexA = Qi.get(conceptRel.conceptA);
5:    If indexA is largest index in Qi
6:      If haven't sent concept to querying agent
7:        Return conceptRel;
8:      End If
9:    End If
10: End Loop
11: Return bestConceptRel;
```

2.5.2 Interest Adaptation Policy

The core mechanism by which agents learn about related domains lies in the interest adaptation policy.

ALGORITHM 2: Interest Adaptation

```
1:  If health isn't perfect and has stagnated (Algorithm 8)
2:   If no concept is selected then select next available concept
3:   If health has been stagnant for Sc cycles
4:     If health is better then  increase trust in agent which
     gave concept knowledge
5:     If health is same then decrease trust in agent which gave
     concept knowledge
6:     For each concept C in  unused concepts
7:      If have or ever had  interest in domainA of C
8:       If trust in suggesting agent of C is higher than random
     number
           between 0 and 1
9:       curConcept = concept C
10       Reduce other areas of interest and exit For loop
11:     End If
12:    End For
13:   End If
14:  End If
15: If health is perfect or have used all concepts then exit
16: k = domain B of curConcept
17:  Ii[k] = min(Io[k], ξr)
```

3. EXPERIMENTATION

Experimentation shows that relations that depend upon other relations can be learned by the system – the transitive problem. Such a scenario cannot be dealt with in a classical referral network. This transitive scenario splits the experts into two groups, one with expertise in domain 1 and the other with expertise in domain 2. One oracle contains two pieces of transitive concept knowledge; the first relates domain 0 to 1 (concept A), the second relates 1 to 2 (concept B). Consumer agents are initially interested in domain 0 but would benefit from learning from experts in domain 1 and 2 (related domains). Thus they benefit initially from utilizing the concept relation 0 → 1. As a consequence of showing interest in domain 1 agents are then provided the concept relation 1 → 2 from the oracle, which in turn provides utility to the consumer agents.

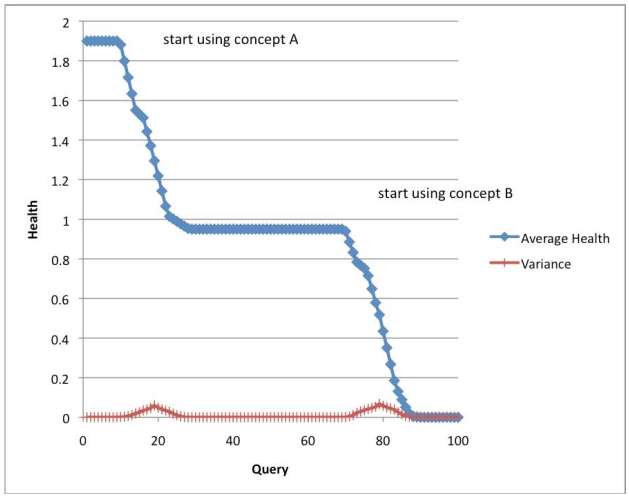

FIGURE 1: Average Health and Variance

Figure 1 depicts the average health and the variance in the health metrics of agents after each query. Clearly, the system has learned to take advantage of the concept relations in order, something that the classical referral network would have been incapable of.

4. CONCLUSIONS

The notion of relational concept knowledge was introduced and shown to effectively allow agents to make use of alternate sources of concept knowledge in a referral network. This is meant to model humans' innate ability to use relational concept knowledge; for instance, when searching online and a certain concept does not provide useful results we then adapt our search based on related concepts. Agents in a referral network are very well adapted to find experts and give referrals; the addition of concept knowledge allows them to leverage this innate ability to learn new and related concepts .

Propagation of concept knowledge ensures that changing meaning can quickly move through the network in a way that is similar to the way in which new subjects, fads or crazes "move" through human society.

5. REFERENCES

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