A Formal View of Social Dependence Networks

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Abstract. In response to the problems that have arisen regarding the terminology and concepts of agent-oriented systems, previous work has described a formal framework for understanding agency and autonomy. In particular, this work made the claim that the framework could serve as a vehicle for the precise presentation and evaluation of models and theories of multi-agent systems. We support this claim by outlining the framework and refining it through adding further levels of detail to formalise the concepts of external descriptions and social dependence networks. Social Dependence Networks are a valuable source of information about the relationships within a multi-agent world. They allow agents to reason about the resources and capabilities of others in order that they may enter into a negotiation to persuade these others to assist them in completing their tasks. By formalising social dependence networks within the framework we are able to identify deficiencies in the original characterisation of the networks and the external descriptions of agents within them. We address these deficiencies, and offer a modified view which removes much of the ambiguity and presents a stronger and more consistent formal model. In reformulating these networks in this way, we also present a case study which shows how the formal framework that has been previously developed can be applied to provide an environment in which we can describe and reason about theories and models of multi-agent systems.

1 Introduction

There is a growing recognition within the multi-agent system (MAS) community of the need to harmonise the efforts being made in different sub-fields and so derive a well-defined discipline of MAS [15]. Previously, we have developed a principled theory of agency and autonomy through the provision of a formal framework which defines these concepts and specifies the relationship between them [8]. This framework was an attempt to provide strong definitions, not only to be precise about the meaning of terms which often have an ambiguous interpretation, but also to serve as an environment in which theories and models of multi-agents systems can be presented, evaluated and developed. In this paper we illustrate how this can be done by adding detail to the framework to describe social dependence networks (SDN) [12]. Specifying SDNs formally in this way
has allowed us to note inconsistencies and ambiguities in the work and suggest possibilities for its development as a useful mechanism for social agents.

As stated elsewhere[8], in the current work, we have adopted the specification language Z [14] for two major reasons. First, it provides modularity and abstraction and is sufficiently expressive to allow a consistent, unified and structured account of a computer system and its associated operations. Such structured specifications enable the description of systems at different levels of abstraction, with system complexity being added at successively lower levels. Second, we view our enterprise as that of building programs. Z schemas are particularly suitable in squaring the demands of formal modelling with the need for implementation by providing clear and unambiguous definitions of state and operations on state which provide a basis for program development. Thus our approach to formal specification is pragmatic — we need to be formal to be precise about the concepts we discuss, yet we want to remain directly connected to issues of implementation. Z provides just those qualities that are needed, and is increasingly being used for specifying frameworks and systems in AI [6, 3, 11] and related areas [4, 5].

The paper begins with a brief description of Social Dependence Networks [12], and continues with a very short outline of the agent hierarchy specified previously [8]. The next section extends and refines the specification of the agent hierarchy to specify SDNs formally. This allows us to evaluate and reason about these mechanisms in terms of our formal framework. We then develop and propose a refined model of dependence networks based on our notions of agency and autonomy. Lastly, we draw conclusions made from this case study of applying the framework we have developed.

2 External Descriptions and Dependence Networks

Dependence networks [12] are structures that form the basis of a computational model of Social Power Theory [1, 2]. They allow agents to reason about, and understand, the collective group of agents that make up the multi-agent world in which they operate. This section introduces dependence networks and external descriptions, data structures used to store information about other agents, based on the work reported by Sichman et al. [12].

External descriptions store information about other agents, and comprise a set of goals, actions, resources and plans for each such agent. The goals are those an agent wants to achieve, the actions are those an agent is able to perform, the resources are those over which an agent has control, and the plans are those available to the agent, but using actions and resources which are not necessarily available to the agent. This means that one agent may depend on another in terms of actions or resources in order for a plan to be executed.

An agent $i$ is denoted by $ag_i$, and any such agent has a set of external descriptions of all of the other agents in the world, denoted by

$\text{Ext}_{ag_i} \overset{\text{def}}{=} \bigcup_{j=1}^{n} \text{Ext}_{ag_j}(ag_j)$

where