



Integrating social power into the decision-making of cognitive agents



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ABSTRACT

Social power is a pervasive feature with acknowledged impact in a multitude of social processes. However, despite its importance, common approaches to social power interactions in multi-agent systems are rather simplistic and lack a full comprehensive view of the processes involved. In this work, we integrated a comprehensive model of social power dynamics into a cognitive agent architecture based on an operationalization of different bases of social power inspired by theoretical background research in social psychology. The model was implemented in an agent framework that was subsequently used to generate the behavior of virtual characters in an interactive virtual environment. We performed a user study to assess users' perceptions of the agents and found evidence supporting both the social power capabilities provided by the model and their value for the creation of believable and interesting scenarios. We expect that these advances and the collected evidence can be used to support the development of agent systems with an enriched capacity for social agent simulation.

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1. Introduction

Research on intelligent autonomous agents has long focused on developing mechanisms to improve how agents sense, keep a record of and interact with their environment [15,27,70]. As part of this progress, in recent years, there has been increasing interest in social concepts that may contribute to new advances concerning social intelligence and believability in agents [17,24]. The acknowledgment of the importance of these concepts has impacted research in several domains [53]. For instance, agents with a model of cultural dimensions were used to develop an intercultural training tool [55], and the application of social cognitive processes is a key factor in the development of virtual humans to train social skills, such as negotiation, interviewing and leadership [47].

Social power is one of the most pervasive social concepts in human societies because of its function as a *social heuristic* [45] for decision-making. It combines diverse and complex decision-influencing social factors, such as formal/informal norms, resource/action dependencies and social status [16]. The impact of social power may be observed in a multitude of social processes, such as coordination, delegation, cooperation, hierarchy and alliance formation, resource allocation and negotiation [16,58,62]. Reinforcing this idea, it has been argued that power is a cognitive mediator for behavior that is fundamental for emulating many social phenomena that depend on the human social mind [17]. Given the ample impact

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of power in people's decisions, which may be observed in scenarios ranging from simple social interactions [45] to social dilemma situations [3,78], the ability to understand power-based social dynamics and emulate them in cognitive agents is of fundamental importance for improving such agents' interactive capabilities [14].

Although the role of power in agent behavior has previously been explored (e.g., [2,16,40,52]), significant research gaps remain with regard to a comprehensive approach to social power, despite the promise of its use in both inter-agent [54] and human-agent interactions [64]. First, social power may derive from different bases (e.g., reward, coercion, legitimate, expert, or referent [37]) with particular dynamics, but many of these bases of power are frequently not addressed in agent models. In particular, most agent models explore social power dynamics related to legitimacy by using social norms and may include reward and coercion mechanisms, but expert and referent power are rarely considered. Second, even in cases in which we can relate agent models with some of these bases of social power, they are not modeled together as a comprehensive system. There is a lack of agent models that integrate each base of social power and its corresponding underlying factors into the agents' processes of sensing, reasoning and strategic interaction with the environment. We see this as a shortcoming that limits the range of social situations that can be handled by such agent systems for either social simulation or the creation of interactive virtual environments.

Therefore, our motivation is to address this limitation by developing an agent model that integrates comprehensive social power dynamics into the decision mechanisms of a cognitive agent architecture. To achieve this, we first explore the links between different bases of social power and their underlying factors, according to social science research, and propose a formalization of the different bases and their underlying mechanics. This formalization serves as the foundation for the development and implementation of a model that integrates social power processes into the typical agent's decision process. We argue that by using this model, general social power dynamics are granted to the agents, empowering them with intelligent social power behavior that is independent of the context, thereby facilitating the adaptation of the agents to different situations.

Several areas of application can benefit from agents endowed with social power. One is education, in which agents are often used to assist people in learning new skills by presenting area-specific challenges and adapting to the learner's characteristics [41,69]. An example is a leadership training application in which a person training to become a leader would learn to efficiently exercise his/her social power over his/her employees. Another application area is social support, in which agents have been used to support people in coping with difficult situations [79]. For instance, agent-based systems can be applied to aid individuals who are subject to intense social pressure (peer pressure) due to group pressure toward the adoption of unhealthy/negative group norms, which can lead to problems such as violence, bulimia, alcohol abuse or emotional distress [35]. An agent capable of reasoning about the social-power forces involved in social situations could help to analyze sources of pressure and propose strategies for resisting the negative influence of peer pressure. A third application area is entertainment; many games present rich worlds, including increasingly more convincing societies of agents, with the aim of increasing player engagement and "suspension of disbelief" [6]. The central goal for these agents (both allies [25] and adversaries [80]) is to increase their believability by ensuring that they exhibit socially competent interactions and behaviors. For example, in role-playing games, agents that are socially intelligent with regard to social power could be used to create virtual actors that are capable of being either friendly or hostile, depending on the various social concepts that underlie social power. A final example of a potential area of application is social simulation, in which the creation of multi-agent simulations is frequently used to explore human social processes. Social power simulations can be used to study societal behavior in response to changes in the parameters affecting social power dynamics and changes in the structure of the social environment. Such simulations can, for example, be used in training applications to assist health-care workers in coping with the complex social power dynamics involved in a hospital infection control setting [72] or for studies of leadership in small societies [81].

In the case of the application of socially intelligent agents in interactive systems (e.g., training applications, serious games and games for entertainment), the agents should present human-like qualities to improve the human-agent interaction. Humans are intrinsically social beings, and as such, they continuously attempt to understand the meaning of the actions of others. In fact, they attempt to understand actions performed by representations of people, as well (e.g., virtual agents [27]). Consequently, visual and/or intellectual believability are key to the effectiveness of an interactive experience [4]. These traits help users to imagine the experience as real without presenting conflicts that might hinder the "suspension of disbelief" and place the plausibility of the experience at risk. Because social power plays a key role in the cognitive processes that mediate behavior, it is also a key factor for ensuring the believability and effectiveness of an interactive agent system. Hence, to explore the applicability and potential impact in this area of the model proposed herein, we implemented the model in the virtual characters of a game scenario and performed a user study to assess users' perceptions regarding the social power awareness of agents. As a result, we obtained evidence supporting the impact and value of the social power capabilities introduced by the model.

This document is structured as follows. In the section titled Related Work, we review previous relevant contributions regarding social power for agents. Then, we present the main theoretical background research applied in our proposed social power model, followed by the developed model itself and the agent architecture used to integrate it into typical agent processes. Afterward, we describe the implementation of the model and architecture in an agent framework and present the Social Theatre environment that was used to perform the user study to assess the impact of the model. Finally, we draw several conclusions.

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