Contexts as reasoning and action frames for multiagent societies

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Abstract. Multiagent models and simulations regularly represent multidimensional social structures and interactions. To control for these complexities, contexts are introduced as reasoning and action frames for multiagent societies. Their principles are explained and an example for an application is provided. The article closes with practical considerations of context design.

Keywords: Agent cognition, contexts, multiagent modeling and simulation, ontologies, reasoning

1 Context-based ontology of social structures and dynamics

As formal, explicit and shared conceptualizations of knowledge that capture the meaning of concepts and their interrelatedness in a domain, ontologies can be used to describe a domain and reason about the concepts in it. Ontologies provide a vocabulary for knowledge representation, so they can also be used to create a model that includes the types, properties and relations of concepts and processes in a domain.

Ontologies of social systems can be complex. To control this complexity, we can introduce explicit meta-models of the building blocks and rules of social ontologies. A valid meta-model is an ontology, but not all ontologies are coded explicitly as meta-models. We first introduce the concept of context as the primary building block of social ontologies and then briefly discuss it using the example of an idealtypical Afghan society as seen through the Afghan district and village.

The proposed context-based ontology approach renders explicit the embedded and interdependent character of agent information and decision making. This

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does not only come in handy when modeling, but also when communicating the model, for example using the ODD protocol [1]. "State variables", a variety of "Design concepts", such as "Sensing", "Interaction" and "Collectives", and many "Details" can be meaningfully explained from a context-based ontology.

2 Principles of context-based ontology design

Context is a minimally sufficient, non-exclusive, nested region of a socio-natural space that explains specific human behaviors in that space. The notion of context divides socio-natural processes into isolated flows by imposing spatial, temporal, cognitive, and agency boundaries on them. The definition of context specifies the following key elements: Behavior, actors, state, context, contingencies, environment and enablers.

Initialization rules specify when a context can occur by itself or result from another context.

Actors are situated in a context. Contexts have one actor, a pair of actors, or a group of actors. Certain contexts require an enabler: an actor perceived by the actors in a context to be responsible for the conditions that lead to the initialization of the context, but is not necessarily a party to the context.

Behavioral process is either scripted or represents an actor's decisions expressed in

- Cognition: The process of retrieving the elements of state variables that characterize actors' attributes and the environment that actors need to reason about. State is a collection of primitives and objects that defines links and relations for an actor for all contexts it is involved in. The notion of information in a specific context defines a subset of state whose relevance to a specific context is determined by agent reasoning.
- Purpose: Desired values or directions of change of state variables for each actor.
- Actions: Activities or interactions that actors believe move them from the state they perceive they are in to another state they desire to be in.
- Reasoning: Mechanisms that enable actors to map information into actions such that actors' objectives are satisfied.
- Contingency triggers: Circumstances in which actors cannot succeed to move toward their stated goal by making decisions or executing scripted processes; with switching to other contexts and adoption of additional behaviors actors can try to rectify this condition.

Actors embedded in real-life situations consider questions that require different approaches to representing actor cognition and reasoning processes. For a training application with well-defined scenarios, many such cognitive processes can be represented as behavioral scripts. However, decision support applications may require representation of a more representative range of human adaptability. For some contexts, actors choose actions based on their historical performance. Other interactions may require actors to either create counterfactual situations in their

"minds" that they have never experienced in real life, or relive those situations they have already experienced and anticipate to find themselves in again.

Contexts are called active when actors can actively make decisions within a given context, for example when actors in the security context decide who to support by providing shelter to insurgents or information to Blue Forces. In passive contexts actors do not make decisions actively, but some of their attributes (such as their attitudes) nevertheless keep evolving. For example, ISAF and Taleban kinetic operations may kill or wound villagers or destroy their property, so villagers need a mechanism for evaluating losses and updating attitudes.

Contexts can be also distinguished into base and contingency contexts. Within the set of base contexts actors can work toward their defined goals assumed there is no friction. Should friction occur and the extant set of base contexts is not sufficient anymore for actors to successfully work toward their goals, contingency contexts act as behavioral repertoire extensions that affords actors to achieve their goals in alternative ways.

A template for the description of a context is depicted in Table 1.

Table 1. Context template.

Context name		
Initialization	Description of which situation or other context initializes the context.	
Actors	Listing of the actors involved in the context.	
Decision making	Information	Definition of which information the actors can access to reason in this context.
	Objective	Name the objectives of the context.
	Actions	List the actions the actors can perform in the context.
	Reasoning	Explain the actors' reasoning mechanism.
	Contingency triggers	List the contingency contexts the context can trigger.
OR		
Scripted outline	Explain the script according to which the agent is expected to behave. If suitable, outline actions and the information requirements for the decision tree.	
Remarks	Mention general remarks.	

3 Applications

Context-based model and simulation development is both, an analytical approach as well as a design procedure, enabling researchers to translate real world social phenomena into formal ontologies that can then be implemented as computer code. The approach is inspired by multiagent approaches to the social and cognitive sciences. Developed for the ATHENA project, it builds upon previous experience by [2–5]. Agents, just like humans, are represented as being embedded in groups of agents where they exhibit varying behavior depending on the particular socio-cultural context they are presently embedded in. It is up to the researcher to identify these contexts and distinguish between necessary and non- necessary contexts, based on need. Some of the contexts found may be culturally specific; some of them may be more general. It is important to realize that the aim is not to find a universal context-based representation of the social phenomenon of interest, but to develop a context-based representation that is valid to the stakeholder, given state of the art subject matter knowledge.

Once a social setting has been sufficiently described in the form of a case study and all contexts necessary to describe the setting have been identified, contexts need to be specified according to Table 1 and relationships between contexts need to be established. Figure 1 provides an idea of how a socio-cultural background is made up of various contexts, how necessary contexts are identified and how relationships between them are established.

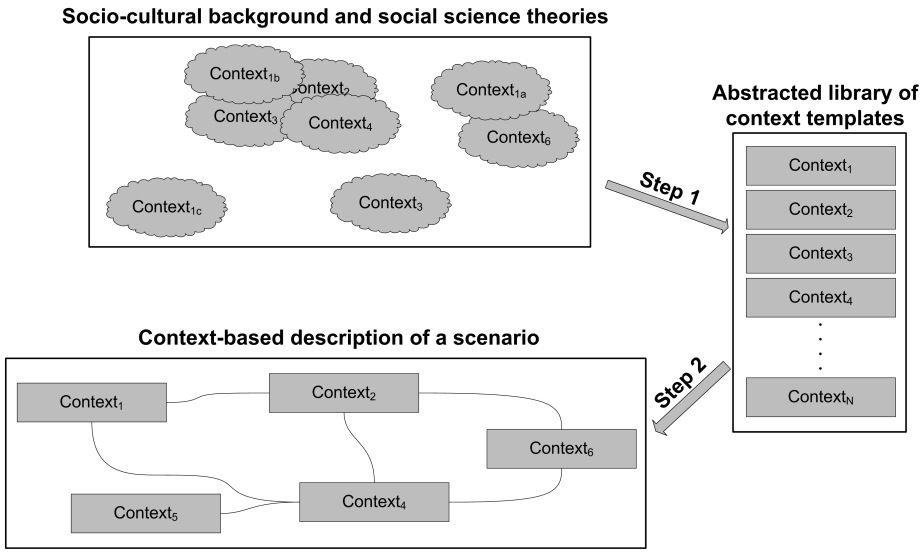

Fig. 1. From the real world to lists of context and context maps.

The simplest form of a context is derived by a semantic transformation: Turning a verb that signifies behavior into a noun that signifies the act, for example, fight to fighting. In designing the context algebra we have followed [6] in separating an agent's intentions, and causes and reasons for agent behavior: The causes of John's fighting, his intentions for fighting and his reasons for fighting are distinct. This epistemological separation stands in sharp contrast to prevalent paradigms in decision sciences that conflate cause and reason for behavior and enables reasoning over agents' observed, expressed and inferred intentions, and causes and reasons for behavior. To achieve this feat, the context algebra relies on the fundamental assumptions of transcendental realism as to the existence of real and knowable human behavior that is socially situated [7], maintaining the ontological reality of he objects of science and their knowability while emphasizing the socially situated nature of knowledge.

Contexts contain agents' interpretations and perceptions that differ from one agent to another and contain other contexts; therefore, agents can have "minds" in which other minds are embedded. However, as building blocks of agents' minds, contexts are objectively real. Different agents can learn, interpret, communicate, act upon and recall contexts differently, giving rise to various forms of rationality bounded by the reasoning mechanisms that connect agent goals to their means [8]; however, contexts are ontologically real and therefore support analysts in creating the "objective" simulation view.

To give a short example against the background of the case of an ideal typical Afghan village and district and actor might fight, i.e. resort to the use of violence due to household dynamics, a land conflict or to defend itself against organized crime. In each context, the actor's intentions to fight, the causes for why he fights and the actor's reasons to fight will be unique because for each context the actor will be uniquely embedded in the time-space continuum of everyday life, leading to a unique, subjective perception of each particular fight.

The context-based approach is potent not only because it lends itself to develop a socio-cultural description of a society that affords multiagent implementation, but also because it starts off as an initially neutral concept that gradually start being filled with whatever socio-cultural content it is applied to. It is thus a cross-culturally employable approach that works not only in Afghanistan, but also say Colombia, Somalia and Yemen.

In Yemen, for example, the political economy of Qat is one of the main drivers of poverty. The crux is that Qat is a lucrative crop due to low labor intensity, providing farmers with cash. Qat distribution networks are atomistic with one intermediary level, the trader, only between the producer and the consumer. Qat is furthermore drought resistant and can be harvested year-round. Qat has also known positive effects, both on the individual and socio-economic/-natural levels – for example being rich in vitamin C, being used as a medicinal drug and contributing to the maintenance of Yemen's land terrace systems – but at present these are offset by its negative effects. After a sound description of these and other essential contexts, necessary contexts need to be identified, say households,

public health and water management, and then be put into relationship with each other according to the evidence available (see Figure 1).

The flexibility of the context-based approach in regards to stakeholder(s), being cross- culturally applicable and able to adopt an emic (actor) and etic (observer) perspective is one of its great advantages.

4 Practical rules for context design

The context-based ontology does not necessarily need to be congruent with each scenario it is designed for to address. The context-based approach is flexible enough to allow for multiple scenarios being executed in a modular way, where only contexts that are needed to run a scenario are also implemented. For any given environment, there may exist a set of "baseline" contexts (not to be confused with base contexts) that is necessary to model each and every scenario. Existence of such a set cannot be guaranteed, though.

It is important to note that the context-based approach is similar to a fractal concept: The contexts reoccur throughout the whole model design and simulation implementation process and are defining for actor behavior and environment. Actors reason in their socio-cultural environment. The cognitive framework as discussed in summary in Section 2 and at length in the report Integrated Schematics of a Cognitive Architecture for Influence Operations therefore needs to enable the actor to cope with reasoning in multiple contexts and take decision which action to choose over a multitude of possible actions.

From a software engineering standpoint, a context is sometimes initialized as an "objective" situation that exists in the main simulation. At other times, a context is initialized as a "virtual" situation that exists only in an actor's mind in order to enable it to view the consequences of its decisions. The ability to initialize contexts from within contexts allows the modeler to augment the context heuristics with a range of adaptability that is difficult to express otherwise.

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