Towards Using *i** for Modelling Mega-Urban Processes

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Abstract. In this paper, we consider the use of i* for modelling social networks in the context of mega-urbanization and water resources. In particular, we discuss, mostly by way of example, issues that are special to this domain such as the need to explicitly model nature or a new kind of agent evolution. Another important issue is the usability of i* by scientists from different disciplines to model mega-urban scenarios without any background in programming or mathematical models.

1 Introduction

In the literature megacities are characterized as cities with at least five to ten million residents. Because of their size, megacities are confronted with severe problems regarding water quality. Especially in cities situated in less developed countries where the government tends to be inefficient in providing proper infrastructures for the fast growing urbanization. Those cities have large areas with informal settlements, for example slums, which are not properly connected to a water grid and much less to sewerage resulting in bad conditions for waste disposal and pollution of various qualities. Other sources of water pollution are factories and even agriculture within the urbanized areas [7].

Because of the size and the fast growth of megacities, it is hard to survey the very complex processes which influence the water quality in such big urbanized regions. To better understand such processes the SiKAMUS[3] project was originated to simulate the behaviour of inhabitants of megacities. During such a simulation the residents are represented by agents who do their work in a megacity while consuming and polluting water.

The project is based on the multi-agent simulation framework SNet [5], which is intended for the modelling and simulation of inter-organizational networks. SNet primarily uses (extended) *i** SR diagrams [12] to describe the relationships between the various stakeholders in such networks. These diagrams are then automatically translated into programs of the action language ConGolog [4],

[3] **S**imulating **K**nowledge-Based **A**gents in **M**ega-**U**rban **S**ystems [2]

which are the basis of the simulations. Here we follow the same methodology and hence focus on SR diagrams as our main *i** modelling tool.

Since the domain experts in our project are hydrogeologists, who often have little background in formal methods (as understood in computer science), another objective is to provide a user-friendly interface to make it possible for those researchers to model and simulate different hydrological megacity scenarios without the need for aid from computer scientists or mathematicians.

In the next section we briefly outline, mainly by way of a small example, first thoughts on how to use and extend SR diagrams to capture our application domain. We then highlight a number of other *i**-related issues that are currently under investigation or still need to be addressed in the future.

2 Modelling Megacities

In our application domain the main use of *i** SR diagrams is to model the relationships between residents of a megacity and their influence on water resources. In the future, this modelling should be done by geologists and urban planners to improve the water quality in megacities. We think that i* is a proper tool for these users because it avoids programming simulations.

The typical use of *i** lies in the early phases of requirements engineering, where the actors can be both humans and technical artifacts such as software systems. In the context of megacities we are mainly dealing with human actors whose behaviour influences the environment they inhabit. The relationships between humans can in principle be modelled by *i**, but as we will see below there are novel features which may call for an extension of the formalism. Since the environment (nature) plays a central role in our domain, there is also the question how to model nature and its interaction with humans.

In order to use the SNet simulation framework for megacity scenarios we had to adapt the *i** dialect used in SNet. In Figure 1 we see an *i** diagram for a small fragment of our application scenario. It depicts the relationship between water users and local water suppliers in a megacity like Hyderabad: A water user tries to get water with a good quality from a reliable resource. She gets the water from a local water supplier who gets the water from a natural resource and maintains a water grid to distribute the water. If the water quality tends to be on a low level, a number of water users may join forces to exert pressure on the water supplier to raise the water quality.

In Figure 1 we used links between agents like in SNet. One of these links used by SNet is the softgoal contribution link. An example for that is the link from the task "improve infrastructure" to the softgoal "supply reliability", which means that an improvement of the infrastructure contributes to the reliability of the water supply. Another SNet link between agents is the decomposition link between the task "accept quality" and "supply water" which, in SNet, means delegating a task to another agent. However, in our domain of megacities such links are better understood as demands. For instance, if a water user accepts the quality of the water, she rather demands water from the local water supplier

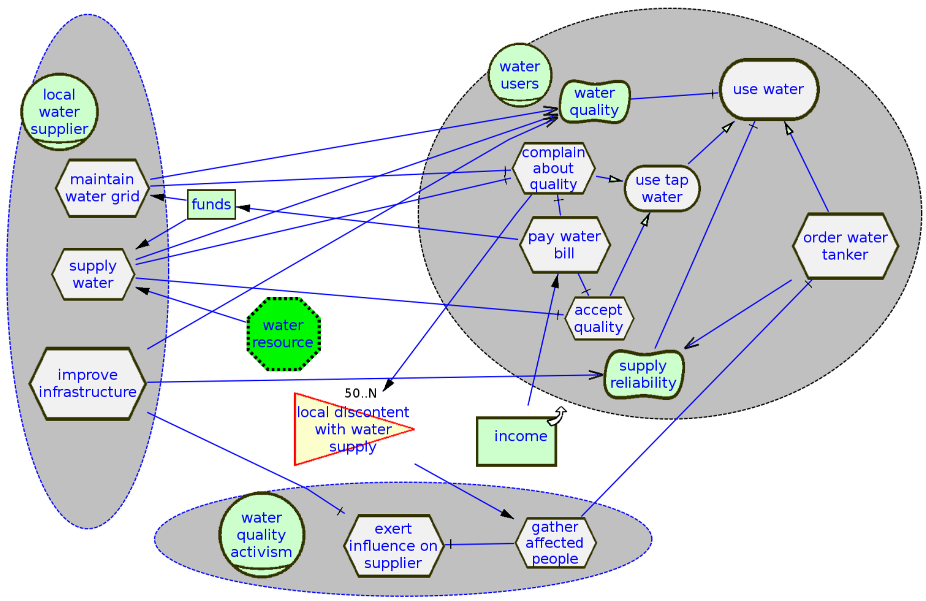

Fig. 1. A small example model of water usage in a megacity.

instead of delegating the task "supply water". Finally, we use SNet links to and from the triangle in the diagram in Figure 1 which is called precondition-effect element in SNet. That is, if the task "complain about quality", the *precondition*, is fulfilled, a value representing the discontent with the water supply is raised. If then a certain threshold for discontent is exceeded, the *effect* is that the task "gather affected people" can be performed.

This means that any water user who complains about the water quality raises the discontent which eventually leads to gathering affected people. If we model it like that, the repeated complaining of one water user is enough to gather affected people. But if we want that gathering people needs more than one water user, there is no obvious way to model this. For that reason we decided to enhance *i** to be able to express that we need more than one agent for issues like raising discontent. In particular, we propose something similar to cardinalities in entity-relationship diagrams. The "50..N" next to the arrow towards the precondition-effect element indicates that more than fifty different agents must be discontented until the effect can occur. Note that this is another kind of threshold than in the precondition-effect elements themselves. There the threshold concerns the quantity of the subject of the element; here discontent. The cardinalities indicate that the effect occurs only if this threshold is exceeded by raising the discontent by, in this case, at least 50 different agents.

Furthermore, to model hydrological scenarios in a megacity we need something to represent nature. That is necessary because we have natural resources like groundwater and natural phenomenons like rain and floods which influence the water level and quality.

In the middle of the diagram in Figure 1 we see a green octagon which is a proposal for a new element. An interesting question is: what kind of resource is the water resource? The problem here is that water is not provided by an agent; it is a natural resource. Furthermore, it is influenced by natural forces like rain. On the other hand, it is influenced by the behaviour of the citizens of a megacity. For instance, the water can be contaminated by waste from informal households and production processes. On the other side, the government can manage to build a water grid and sewerage to raise the quality of the water resources. Because the resource is not provided by some agent and is influenced by many others, we think that we cannot use the original i^* resource element for natural resources. Therefore, we propose a new element whose first version is the green octagon in Figure 1. The link from this element to the task "supply water" means that this task is only possible to perform if the water resource provides water.

In addition, in Figure 1 we also use resources which are provided from agents rather than from nature. For instance, the link to the resource element "funds" in the diagram means that the water users raise the funds by paying their water bills. Furthermore, the links from "funds" to the tasks "maintain water grid" and "supply water" mean that these tasks can only be performed if the funds are sufficient. The nature resources as well as these resources are not used in SNet.

Finally, a problem occurring in modelling megacities is that diagrams soon become very large, often with many links between elements, which users find confusing. For that reason we need a proper approach to make such big diagrams manageable. A first attempt to overcome this problem can be seen in the income resource in Figure 1. We propose to modularize the diagram by connecting separate diagrams with linking elements in the diagram linking to other diagrams. The small arrow at the right upper corner at the resource element indicates a link to the diagram with the provider of this resource.

In conclusion, i^* appears to be a promising tool for modelling actors and their interdependencies in megacities, but some additional features may be needed for this purpose.

As in SNet the i^* diagrams serve as input for a translation into ConGolog programs, whose execution generate simulations for particular instantiations of the given network. In our case additional information is provided by geodata which describes the surroundings of agents in a megacity. In particular, we make use of existing data about groundwater quality, water management and urban growth in megacities like Hyderabad (India), Guangzhou (China) and Yogyakarta[4] (Indonesia) [10, 11, 8]. From the gathered data a semantic geodatabase was built using OWL [3]. It contains information about land-use units, where each of them represents a piece of land in a megacity. In short, it is stored for what this

[4] Although Yogyakarta is not a megacity it is considered because of its fast growth which is comparable with that of megacities.

particular land is used, what kind of housing and workplaces are placed on it and what is located in the neighbourhood. Additionally, it is stored what geological properties the land has.

While the information contained in the OWL database is crucial to obtain faithful simulations, it is unclear at this point how much of the OWL ontology needs to be reflected in the *i** model.

3 Ongoing and Future Work

We are in the middle of investigating how we can model megacities. Therefore, the proposed adaptations of *i** are likely not the final versions. To complete our work we still have to consider the following.

For instance, if we think about natural phenomenons, we can also think about representing nature as an actor. But in contrast to the predominant view in *i**, this actor acts according to natural laws and without intentions.

This notion of nature then can provide natural resources. The work is still in progress, so we have no complete concept for this ready. Furthermore, we still need a semantics for natural elements. Since, as mentioned above, the ontology stored in an OWL database determines the surrounding of an agent, we think the semantics of natural elements has to follow the structure in the OWL ontology. For example, if we instantiate the water resource element in Figure 1, we dispose where an agent is situated in the megacity and depending on this we set the availability of this resource.

Furthermore, the third role in the diagram in Figure 1 besides "local water supplier" and "water user" is "water quality activism." This should be played by some agent who exerts influence on the water supplier and gathers people to raise the pressure. But if we think about people who complain about the government, it must be more than one agent which plays this role. In addition, these have to be the same agents which play the role "water user." For this, agents have to change their roles; it should be possible that a water user becomes an activist. Roesli et al. [9] proposed two ways of agent evolution. The first way is to change a role if a certain threshold is exceeded. For instance, a role is changed after getting some qualifications. This happens automatically after reaching the needed qualifications. The second approach needs planning to make a role change which means that it happens not automatically but with deliberation of an agent. We think that the second approach fits most to the domain of discourse because, for example, a resident of a slum needs some deliberation until she turns into a protester against the government. One of our research objectives is to investigate how we can model deliberation according to [9] and how we can enhance that. For example, we want to model a goal-oriented role change. That is, we think about a meta-goal which always is the main goal through all role changes.

To modularize huge diagrams we proposed linking elements which connect separated diagrams. Alencar et al. [1] presented two ways how to improve modularity of *i** diagrams. First, they proposed so called aspects as new actor-like elements in *i**. Second, they proposed a model transformation approach to get models with better clarity. Another approach for our project might be different views of the same diagram, where some of its elements are hidden. An example of such views is the concept of scenarios in the User Requirements Notation (URN) [6]. It remains to be seen how approaches such as [1,6] can be adapted to arrive at user-friendly tools to manage large i* diagrams.

In this paper we highlighted a number of issues that arise from using i* to model actors in mega-urban cities with a focus on water resources. In many ways we have only scratched the surface of the problems in this interesting domain. In the future we hope to report on new findings, also regarding our long-term goal of simulating agents in mega-urban scenarios.

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