

An Approach for Hospital Planning with Multi-Agent Organizations (Extended Abstract)

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As a response to increasing demands and limited resources, the Danish public healthcare sectors are establishing emergency departments with the vision of offering acute treatment with the patient in focus [1]. With this vision arise challenges such as keeping waiting queues short and maintaining a staff work flow that balances acute and scheduled treatments. Existing work [2–6] shows that simulation can be used for decision support in planning hospital resources but provides little insight into the staff work flow. We proposed in our full paper [7] an approach for gaining such insight that applied agent-based simulation and research from the AI-communities [8].

We proposed using the AORTA framework for enabling organizational reasoning in agents [9,10] as an outset for providing this insight through agent-based simulation and formal logic [11,12]. To demonstrate the applicability of the approach, we showed how an informal description of acute patient treatment can be represented as a model in the AORTA framework.

In this extended abstract we show the process of creating the AORTA model. We use the following fragment of stages (1,2) and conventions (a,b,c) from the informal description in our full paper [7] as a working example in creating the model:

1. *Triage*: A nurse carries out the triage process on the patient.
2. *Diagnosis and Treatment*: A doctor performs a diagnosis and initial treatment on the patient.
 - a. Nurses fill out a triage form for the patient as part of the triage.
 - b. Doctors in the specialized departments take care of scheduled treatments.
 - c. Initial treatment of patients may require assistance from doctors from different specialized departments.

An important part of organizational reasoning is that humans generally act as expected, but are also able to do otherwise. AORTA gives agents the same flexibility by having agents maintain organizational knowledge separately from personal beliefs. In the reasoning cycle of the agent it then queries both its organizational knowledge and its personal beliefs. The organizational knowledge is represented as logic predicates in an *organizational metamodel*. Table 1 shows a subset of the symbols that can be used to define the metamodel and the remaining part of the paper describes the process of creating a metamodel for the above informal description of acute patient treatment. The role-predicates define roles and their main objectives. The stages in the informal description

Predicate	Informal meaning
$\text{role}(\text{Role}, \text{Objs})$	<i>Role</i> is the name of a role and <i>Objs</i> is a set of main objectives of that role.
$\text{cond}(\text{Role}, \text{Obj}, \text{Deadline}, \text{Cond})$	When the condition <i>Cond</i> holds, <i>Role</i> is obliged to complete <i>Obj</i> before the objective <i>Deadline</i> .

Table 1. Subset of predicates of the AORTA metamodel and their informal meaning.

$\text{role}(\text{nurse}, \{\text{triage}(\text{Patient})\})$
$\text{role}(\text{acute_doctor}, \{\text{acute_treatment}(\text{Patient}), \text{treatment_plan}(\text{Patient})\})$
$\text{role}(\text{specialized_department}, \{\text{scheduled_treatment}(\text{Department}, \text{Patient})\})$
$\text{role}(\text{specialized_doctor}, \{\text{scheduled_treatment}(\text{Department}, \text{Patient})\})$
$\text{cond}(\text{nurse}, \text{fill_form}(\text{Patient}, \text{Nurse}), \text{triage}(\text{Patient}), \text{admission}(\text{Patient}))$
$\text{cond}(\text{acute_doctor}, \text{specialized_treatment}(\text{Patient}, \text{specialized_doctor}), \text{acute_treatment}(\text{Patient}), \text{specialistNecessary}(\text{Patient}, \text{specialized_doctor}))$

Table 2. Metamodel based on the stages and conventions in the informal description.

mention: a *nurse* that carries out triage and an *acute doctor* that carries out acute treatment. Additionally, convention (c) mentions a *specialized department* that carries out scheduled treatments and *specialized doctors* that carries out scheduled treatments work in the department. The cond-predicates are deontic temporal statements that define conditions on how the agents should complete objectives when enacting a role. The conventions in the informal description mention: *nurses* should fill in the triage form before they finish the *triage* when a patient has been admitted, and that *acute doctors* should involve a specialist in the acute treatment if necessary. Table 2 shows the predicates of the metamodel for acute patient treatment.

We have shown how the informal description of the emergency department scenario can be represented in the AORTA framework for adding organizational reasoning to agents. Our work provides an outset for gaining insight into the staff work flow through agent-based simulation and logic. JaCaMo [13] offers another framework for implementing agent organizations that was used by the winning team in the Multi-Agent Programming Contest 2016. Future work includes investigating to what extent agent programming frameworks and process mining can facilitate agent-based simulation. Process mining is a method for discovering and extending process models based on event logs. In line with [14–16], we aim to use this method to extend the agent model and do quantitative evaluation based on logs of real world activity.

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