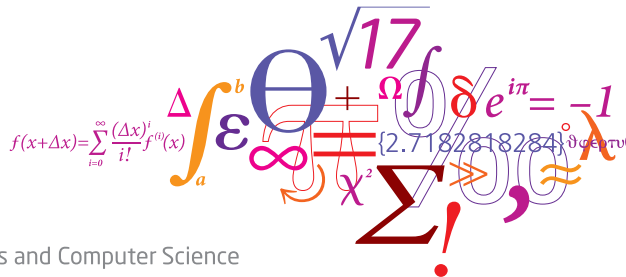# An Approach for Hospital Planning with Multi-Agent Organizations
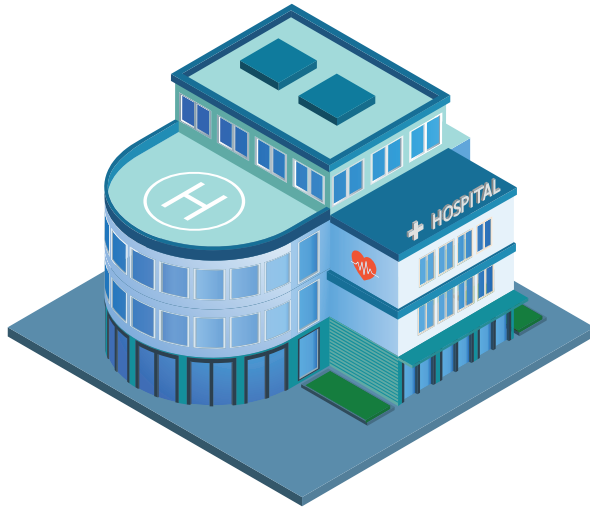
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$$f(x+\Delta x)=\sum_{i=0}^{\infty}\frac{(\Delta x)^i}{i!}f^{(i)}(x)$$

$$\Delta \quad \int_a^b \quad \varepsilon \quad \Theta \quad \sqrt{17} \quad f$$

$$\Omega \quad \oint \quad \delta \quad e^{i\pi}=-1$$

$$\infty \quad \{2.718281828\} \quad \vartheta \phi \in \rho \tau \psi \quad \lambda$$

$$\chi^2 \quad \sum \quad ! \quad \approx \quad 00$$

Designed by macrovector / Freepik

Motivation

Why simulation?

- Dynamic complex system.

- Forecasting.

Why agents?

- Interaction involving nurses, patients, computer systems, departments, etc.

- Normative – vague or drifting rules depending on viewpoints.

What are the stages in the patient treatment process?

1. *Admission* Arrival of the patient in the department; check in at reception.

2. *Triage* A nurse carries out the triage process on the patient.

3. *Diagnosis and Treatment* A doctor performs a diagnosis and initial treatment on the patient.

4. *Round-up* The patient receives a plan for further treatment and leaves the department.

How are the patients and staff expected to behave?

1. Patients should arrive in the admission area, either by their own means or by ambulance.

2. Patients must wait in the admission area until they have been attended to by the reception.

3. After the admission, patients must wait in a designated room until called by a triage nurse.

4. The nurse who carries out the triage must fill out a triage form for the patient.

5. After the triage, patients must wait in a designated room until called by a doctor.

6. Patients are involved in making their plan for further treatment.

7. The doctors in the specialized departments take care of scheduled treatments.

8. The initial treatment of patients may require assistance from doctors from specialized departments.

FAM as multi-agent organization

Active agents - example: individual knee specialist

• Detailed goal achieving Belief-Desire-Intention (BDI) model.

  • input: percepts, messages
  • output: action

Passive agents - example: IT-system

• Primarily reactive rule-based model

  • input: vector of messages
  • output: vector of actions

External agents - example: specialized department

• Vague goal achieving BDI model

  • input: vector of messages
  • output: vector of requests

Agent organization framework - AORTA

Metamodel predicates

Predicate	Informal meaning
role(*Role*, *Objs*)	*Role* is the name of a role and *Objs* is a set of *main* objectives of that role.
obj(*Obj*, *SubObjs*)	*Obj* is an objective that has *SubObjs* as a set of sub-objectives.
dep(*Role$_1$*, *Role$_2$*, *Obj*)	*Role$_1$* depends on *Role$_2$* in order to complete *Obj*.
rea(*Ag*, *Role*)	Agent *Ag* enacts *Role*.
cond(*Role*, *Obj*, *Deadline*, *Cond*)	When the condition *Cond* holds, *Role* is obliged to complete *Obj* before the objective *Deadline*.
obl(*Ag*, *Role*, *Obj*, *Deadline*)	Agent *Ag* is obliged to enact *Role* to complete *Obj* before *Deadline*.
viol(*Ag*, *Role*, *Obj*)	Agent *Ag* enacting *Role* has violated the obligation to complete *Obj*.

Andreas Schmidt Jensen, Virginia Dignum and Jørgen Villadsen.

Based on stage descriptions

- *Diagnosis and Treatment* A doctor performs a diagnosis and initial treatment on the patient.

- *Round-up* The patient receives a plan for further treatment and leaves the department.

  $$\text{role}(patient, \{acute\_treatment(Patient), treatment\_plan(Patient, Plan)\})$$

Based on norms

- The doctors in the specialized departments take care of scheduled treatments.

  $$\text{role}(specialized\_doctor, \{scheduled\_treatment(Department, Patient)\})$$
  $$\text{role}(specialized\_department, \{scheduled\_treatment(Department, Patient)\})$$

Objectives in the FAM metamodel

Based on stage descriptions

- *Diagnosis and Treatment* A doctor performs a diagnosis and initial treatment on the patient.

- *Round-up* The patient receives a plan for further treatment and leaves the department.

$$\text{obj}(treatment\_plan(Patient), \{acute\_treatment(Patient)\})$$

Based on norms

- The doctors in the specialized departments take care of scheduled treatments.

$$\text{obj}(scheduled\_treatment(Department, Patient), \{\})$$

Based on stage descriptions

- *Admission* Arrival of the patient in the department; check in at reception.

$$\text{dep}(patient, receptionist, admission(Patient))$$

Based on norms

- The doctors in the specialized departments take care of scheduled treatments.

$$\text{dep}(specialized\_department, specialized\_doctor,$$
$$scheduled\_treatment(Department, Patient))$$

Conditions in the FAM metamodel

Based on norms

- Patients should arrive in the admission area, either by their own means or by ambulance.

- Patients must wait in the admission area until they have been attended to by the reception.

$$cond(patient, wait\_in(Admission\_area), admission(Patient),$$
$$arrivedBy(Patient, Self) \lor arrivedBy(Patient, Ambulance))$$

FAM metamodel

role(*patient*, {*acute_treatment*(*Patient*), *treatment_plan*(*Patient*, *Plan*)})
role(*receptionist*, {*admission*(*Patient*)})   1
role(*nurse*, {*triage*(*Patient*)})   2
role(*acute_doctor*, {*acute_treatment*(*Patient*), *treatment_plan*(*Patient*)})   3, 4
role(*specialized_doctor*, {*scheduled_treatment*(*Department*, *Patient*)})   g
role(*specialized_department*, {*scheduled_treatment*(*Department*, *Patient*)})   g

obj(*treatment_plan*(*Patient*), {*acute_treatment*(*Patient*)})   4
obj(*acute_treatment*(*Patient*), {*triage*(*Patient*)})   3
obj(*triage*(*Patient*), {*admission*(*Patient*)})   2
obj(*admission*(*Patient*), {})   1
obj(*scheduled_treatment*(*Department*, *Patient*), {})   g

dep(*patient*, *receptionist*, *admission*(*Patient*))   1
dep(*patient*, *nurse*, *triage*(*Patient*))   2
dep(*patient*, *acute_doctor*, *acute_treatment*(*Patient*))   3
dep(*patient*, *acute_doctor*, *treatment_plan*(*Patient*))   4
dep(*specialized_department*, *specialized_doctor*,
   scheduled_treatment(*Department*, *Patient*))   g

cond(*patient*, *wait_in*(*Admission_area*), *admission*(*Patient*),
   arrivedBy(*Patient*, *Self*) ∨ *arrivedBy*(*Patient*, *Ambulance*))   a, b
cond(*patient*, *wait_in*(*Room*), *triage*(*Patient*), *admission*(*Patient*))   c
cond(*nurse*, *fill_form*(*Patient*, *Nurse*), *triage*(*Patient*), *admission*(*Patient*))   d
cond(*patient*, *wait_in*(*Room*), *acute_treatment*(*Patient*), *triage*(*Patient*))   e
cond(*acute_doctor*, *involve_patient*(*Patient*, *Plan*),
   treatment_plan(*Patient*, *Plan*), *acute_treatment*(*Patient*))   f
cond(*acute_doctor*, *specialized_treatment*(*Patient*, *specialized_doctor*),
   acute_treatment(*Patient*), *specialistNecessary*(*Patient*, *specialized_doctor*))   h

Process mining

Can we improve the model?

- Event logs

- Repair the metamodel

- Adjust agents to match behavior of a specific department

Related work

Agent organization frameworks

- Moise (JaCaMo)
- Logic of Agent Organizations

Process mining in the hospital setting

- Discovering process models with Prom – procedural models
- Reparing declarative models (LTL based) based on event logs

Conclusions and future work

Conclusions

- FAM as multi-agent organization: active, passive, and external agents.

- FAM as AORTA metamodel based on:
    - Previous work on agent simulation for ED
    - Official descriptions of FAM

Future work

- Work with AORTA in proof assistants.

- Implementations of agent organizations in an agent simulation framework.

- Process mining for repairing the model based on event logs.

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