Addressing Agent Autonomy in Business Process Management - with Case Studies on the Patient Discharge Process

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1. Introduction

Business Process Management (BPM) has arisen as a new trend in information technology that aims to unify disciplines such as Process Modeling, Simulation, Workflow, Enterprise Application integration and Business-to-Business integration into a single standard [Owen 03]. The recent initiatives have emphasized process models that can lead directly to automated process execution, e.g., the Business Process Management Notation [Owen 03; White 03] and the Business Process Management Languages [Ghalini 02]. While the link to process execution is crucial, it is equally important to have models that can express the complexities of business processes in their full organizational context, and be able to support reasoning about alternate process designs. In today's fast paced changing world, understanding the impacts of proposed changes is a must. Experience from business process reengineering indicated that many projects failed to achieve desired results because human and social organizational issues were overlooked. Many business processes are sustained by human actors who are able to exercise discretion in response to changing or unforeseen circumstances, deviating from standard procedures [Suchman 87] and working around automated processes embedded in inflexible information systems [Gasser 86].

Agility, flexibility, and agent autonomy are therefore important characteristics in organizational work that business process models should be able to capture and reason about. During the early stages of analyzing how work is done and in redesigning how it could be done, a business process should not be viewed as a rigidly defined set of actions and flows, but as relationships among semi-autonomous actors. The actors have expectations on each others' behaviors and actions, yet they are free, within limits, to act autonomously to achieve goals and fulfill expectations.

A number of techniques have introduced the explicit modeling of goals to support the design of business processes [Kueng 97] [Rolland 98] [Kavakli 99] [VanLamsweerde 01] [Bubenko 01] [Nurcan 03]. Goals are used, during design, to systematically guide the refinement of process steps, and to select among alternatives. However, the processes that result from the design do not have agents that can freely pursue the goals defined in the work process, or how those freedoms may be constrained.

To model and reason about business processes, one needs to be able to express where in a process the agent has freedom and where it must be carried out in a specific way. These distinctions are important since a process can succeed or fail depending on how the freedoms and constraints are designed.

In the ***i**** framework [Yu 97], processes are modeled as relationships among actors. Each actor can potentially act autonomously, but is constrained by its dependency relationships with other actors. This allows us to model and analyze processes in terms of a set of social relationships:

- How is a business process accomplished through the collaboration and cooperation of otherwise self-interested actors?
- What freedoms does an agent have to accomplish its goals?
- How critical is a dependency from one agent to another?
- What if the agent that I depend on fails to deliver a committed dependency?
- What design alternatives do I have in (re)allocating freedoms and constraints?

Unlike other goal-oriented modeling techniques, where goals are reduced during process design into a process model that no longer have goals, in i*, goals are embedded in the process model as relationships among agents. This has the added benefit that emerging intelligent software agent technology can be used to implement the more flexible process model allowing freedoms and constraints [Yu 01; Castro 02]. Compared to conventional information systems, agent-based systems have the potential to offer greater flexibility, enhanced functionalities, and better robustness, reliability, and security.

The ***i**** framework has been presented in a variety of settings [i*]. In this paper, we focus on the concept of agent autonomy. We also show how ***i**** can be used as a front-end to BPM technology in order to bring autonomy into consideration and diminishing the gap from BPM and agent software.

An example from the health care domain is used to illustrate the need for freedoms and constraints in modeling complex work processes. We have used the framework to assist in the analysis and redesign of the patient discharge process in three major hospitals in Toronto with encouraging results.

2. Modeling the Business Process Through Agents Relationships

The ***i**** framework comprises of Strategic Dependency (SD) and the Strategic Rationale (SR) models. The SD model depicts a process as a network of dependency relationships among actors. In ***i****, a dependency is a relationship in which one actor (the *depender*) depends on another actor (the *dependee*) for something (the *dependum*) to be achieved. A dependum can be a goal, task, resource, or softgoal, reflecting the types of freedom allowed by the relationship. A goal dependency is one in which one actor depends on another to bring about a certain condition or state in the world, while the depended actor (the dependee) is free to, and is expected to, make whatever decisions are necessary to achieve the goal. Thus, it also indicates that one actor does not care how the other actor will achieve this goal. For example, the patient depends on the nurse to accomplish the goal of being assessed. It is a goal because the patient does not care specifically how the nurse will achieve that goal. On the other hand, if the depender does care this goal would be represented as a task. A task dependency means that the actor who is delegating this task specifies how the task is to be performed. For example, a social worker will depend on the attending physician to accomplish the task of filling some of the discharge forms. It is a task because the social worker actually cares how the attending physician will do that.

While the SD models focus on external relationships among actors, the SR models describe the intentional relationships that are "internal" to actors, in terms of process elements and the rationale behind them.

Figure 1 shows part of one SD model used to model the patient discharge process during our case studies. This figure illustrates the fact that a Patient has the freedom to use whatever means he/she wants to choose a service that will provide Post Acute Care (PAC) (1). Patients would not consent on going to a nursing home that does not match their expectations. Furthermore, each patient may use different criteria to choose (proximity, quality of services) and constraining that freedom would be impossible. Thus, whatever alternative one might want to suggest improving the quality of the discharging process, it must be compatible with the freedom Patient has to choose among different services. Therefore, this is represented as a goal dependency that Social Worker has on Patient. If the patient was compelled to use pre-defined standards or steps given by Social Worker for choosing a PAC service, this would be represented as a task dependency.

Figure 1 also shows that ER Physicians (Emergency Room Physicians) do not have an option on how they will fill the discharging forms (2). It has to be done using the eDischarge System; its use is enforced by the Community Care Access Center (Organization responsible for managing most of the PAC services in Ontario – CCAC). As Social workers depends on these forms to be filled so they can apply for a PAC service and since it has to be done in a pre-determined way, it is modelled as a task dependency between Social Workers and ER physician. Here we represent what happens to patients that goes to the Emergency Room (ER) and are discharged from there without going for the ward.

Another example of goal dependency is the one Nurses have on Physicians (3). Nurses can only discharge a Patient after she gets the Physician's authorizations. The Nurse does not constraint the Physicians in this relationship. In medical "even if a guideline illustrate the steps to follow in pre-defined situations, it may happen either that a new, unpredictable situation arises, or the physician, that is the final decision-maker, is not always compliant with the guideline" [Stefanelli 01]. Therefore, it is modelled as a goal dependency that Nurses have on Physicians.

We can also see in Figure 1 that patients need to know which the discharging policies (4) are. This is represented as a resource dependency between Patient and Social Worker. A resource dependency happens whenever one agent depends on another to have some sort of entity (physical or informational) available. The numbers showed in Figure 1 are just for the reader's reference. They do not imply any sequence of events

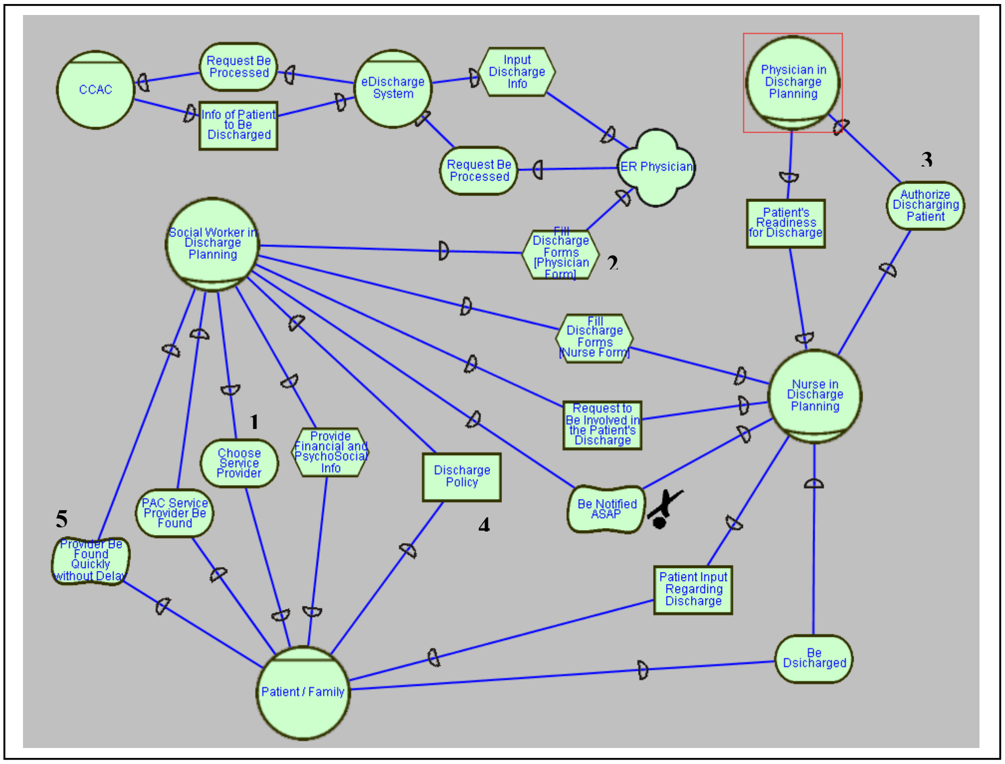

CCAC
Request Be Processed
Info of Patient to Be Discharged
eDischarge System
Input Discharge Info
Request Be Processed
ER Physician
Physician in Discharge Planning
3
Authorize Discharging Patient
Patient's Readiness for Discharge
Social Worker in Discharge Planning
Fill Discharge Forms [Physician Form]
2
Fill Discharge Forms [Nurse Form]
Nurse in Discharge Planning
Request to Be Involved in the Patient's Discharge
1
Choose Service Provider
Provide Financial and PsychoSocial Info
Discharge Policy
Be Notified ASAP
4
5
PAC Service Provider Be Found
Provider Be Found Quickly without Delay
Patient Input Regarding Discharge
Be Dsicharged
Patient / Family

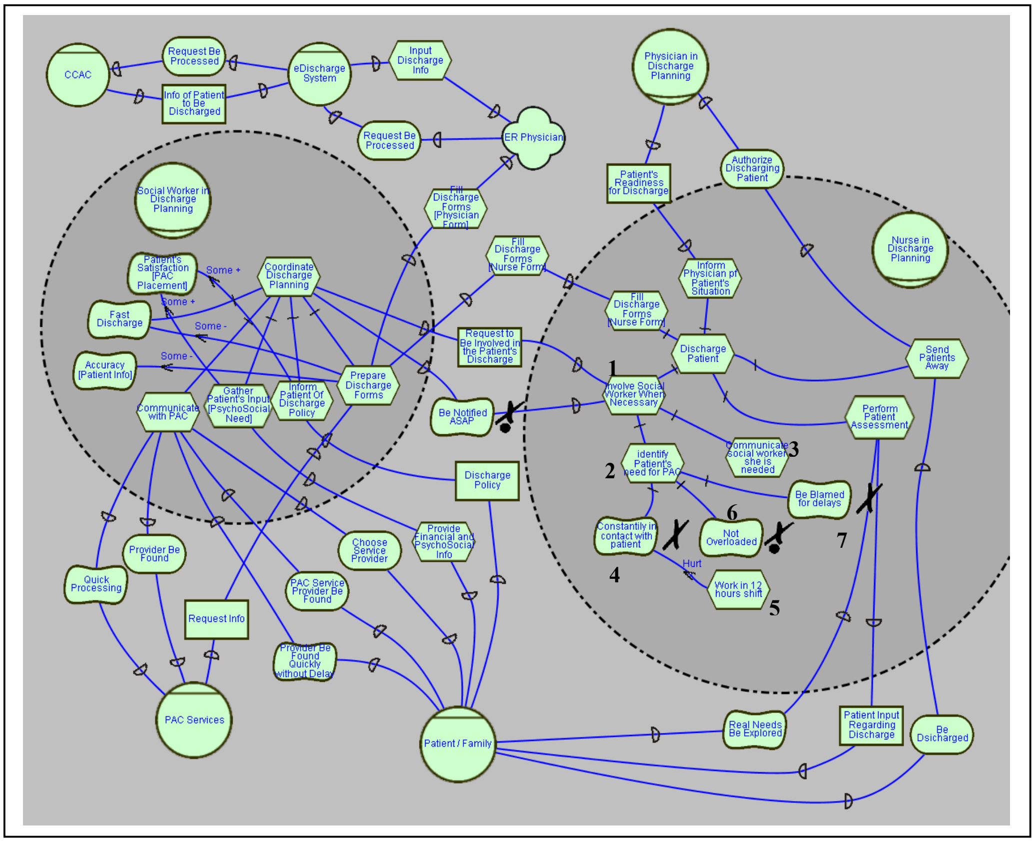
Figure 1 – Part of the Process Model for one of the hospitals

Softgoals are similar to goals except that they do not have clear-cut criteria of satisfaction. They are said to be satisficed if they are satisfied within acceptable limits [Simon 81]. They commonly express qualitative goals. We can see for example in Figure 1 that the Patient expects to have a provider found quickly (5). What amount of time would satisfice this softgoal is not precise. It may change with the kind of provider that patient is expecting, or even from patient to patient. It is modelled here that social workers must try to satisfice this goal the best they can. Within SR models one can refine these softgoals to increasingly concrete softgoals until they are operationalized into tasks.

3. Analyzing the Process

Aside from SD models, to model a business process we need SR models to express the rationales that each agent has about processes and alternatives. When modelling business process we elicit SD models and refine them into SR models so we can deeply understand the current process and explore new alternatives.

Different alternatives (typically represented as tasks) contribute differently to various softgoals allowing us to identify and assess which approach could be better in which situation. We can also visualize possible threats to the achievement of an agent's goals appearing as negative contributions to softgoals. For example, in Figure 2 we can see that the task of preparing discharge forms contributes negatively (*some* -) to satisfice the Fast Discharge softgoal. This negative contribution may lead the engineer to think about alternative solutions to this task. It could range from delegating this task to another human agent, to having a software agent doing that, or eventually negotiating with the PAC services to develop easier forms.


CCAC
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Patient's Readiness for Discharge
Authorize Discharging Patient
Social Worker in Discharge Planning
Fill Discharge Forms [Physician Form]
Fill Discharge Forms [Nurse Form]
Nurse in Discharge Planning
Inform Physician pf Patient's Situation
Fill Discharge Forms [Nurse Form]
Patient's Satisfaction [PAC Placement]
Some +
Coordinate Discharge Planning
Some +
Fast Discharge
Some -
Request to Be Involved in the Patient's Discharge
Discharge Patient
Send Patients Away
Accuracy [Patient Info]
Some -
Prepare Discharge Forms
1
Involve Social Worker When Necessary
Communicate with PAC
Gather Patient's Input [PsychoSocial Need]
Inform Patient Of Discharge Policy
Be Notified ASAP
Perform Patient Assessment
Communicate social worker she is needed
3
Discharge Policy
2
identify Patient's need for PAC
Be Blamed for delays
6
Constantly in contact with patient
Not Overloaded
7
Provider Be Found
Choose Service Provider
Provide Financial and PsychoSocial Info
Quick Processing
Hurt
4
PAC Service Provider Be Found
Work in 12 hours shift
5
Request Info
Provider Be Found Quickly without Delay
PAC Services
Patient / Family
Real Needs Be Explored
Patient Input Regarding Discharge
Be Dsicharged

Figure 2 – Part of the Strategic Rationale model for one of our case studies

Using a qualitative reasoning procedure [Chung 00], goals and softgoals can be evaluated to take a value ranging from *denied* to *satisficed,* through values such as *weakly denied*, *undefined* or *weakly satisficed*. Every softgoal that is not at least weakly satisficed represent a potential area for improvements and therefore must be carefully analysed.

Take for example the softgoal Be Notified ASAP in Figure 2. During the case study in one of the hospitals, we were told that this softgoal was frequently not satisficed. We started to investigate why this happens and we could model what can be seen inside Nurse. We see that the softgoal Be Notified ASAP depends on the goal involve Social Worker when necessary (1).

We can also see that this goal may be achieved by identifying the patients' need for PAC (2) and further communicating it to the Social Worker (3). Now we want to identify what is necessary so Nurses can efficiently identify patients' need for PAC. Thus, we decompose this task into three softgoals. One softgoal shows the need for Nurses to be constantly in contact with the patient so they can easily understand their needs and constraints (4). This softgoal is hurt by the fact that they work in 12 hours shifts (5). Therefore we evaluated this softgoal as being denied.

The other softgoal shows the need for Nurses not to be overloaded since in this case they have less time to spend with patient and even obvious needs can be missed (6). Talking to some of the stakeholders, we realized that this softgoal is frequently not satisficed because the hospital is frequently operating near 100% capacity. Therefore we evaluated this softgoal as weakly denied.

Finally, we have a third softgoal that shows the need for nurses to be accountable for delays in the process if they do not involve the Social Worker when needed (7). During the study at one hospital, it was found that this softgoal was denied. The same way as in figure 1 the numbers appearing in Figure 2 do not imply any sequence of events.

Analysing the model we could see that the facts mentioned above resulted in the softgoal Be Notified ASAP being weakly denied. In fact, the complete freedom Nurses have on deciding the way they will assess the patient plays an important role on the failure to accomplish this softgoal.

It remains now to evaluate different alternatives to solve this problem. The first alternative was to somehow constraint Nurses' freedom imposing a set of prescribed steps to be followed in order to minimize the problem of not recognizing Patients' need for PAC. This would be a challenge since Nurses are overloaded and not trained for following such guidelines. Another alternative was shifting the goal of involving social worker to a software agent that could recognize through reasoning on patients' files that PAC would be needed. Although desirable and possible to be done, this was established as a long term goal since it demands several changes in the current system and might conflict with some requirements for the new software that will be developed until 2005 to support the paperless process. One more alternative we found was to create a new role, to be played by a Nurse, to assess Patient in discharging process. This role will have to be played daily by a registered nurse whose main concern would be to assess Patients regarding their needs for discharge. Each Nurse playing this role would be responsible for several patients and would be directly blamed if any delays in involving social worker when needed implicates in retaining the patient more than necessary in the hospital. Since this role will be closely linked to patient, we realized that this role could also be responsible for preparing discharge forms currently done by Social Workers This way, Social Workers would have more time to better assess patients in psychological and financial aspects. Yet, being a new role makes it easier to establish a set of procedures to be followed by those playing this role, hence autonomy for those playing this role will be constrained is some extent When we modelled this option we identified that the Nurse playing this role could easily get overloaded because of the many controls needed to follow-up PAC requests. Thus, in order for Nurses to efficiently deal with the forms and to follow-up requests for PAC an yet be able to cope with patients needs we envisioned the need for a software agent to manage these tasks

Once a process has been established which manages to get the agreement of the various stakeholders, supporting us much as possible their needs and expectations, we may then use BPM techniques and languages to model and analyze the business. Although it is future work we show below some preliminary ideas on how should one map ***i**** models to BPMN.

1. Identify the actors. Each one will be a candidate to be a pool
2. For each actor chosen as pool, lets say actor A, identify which other actor depend on actor A and vice versa. Each actor may be represented in a separate lane close to the one used to model actor A.
3. Identify goal dependencies; they will represent communication as a black box. Identify to which task or goal in actor A this dependency is linked. If it is linked to a goal or to a task that is further decomposed represent this task/goal as a process in the lane for actor A and link it to the other lane (e.g. actor B) using appropriated messages. Otherwise do the same representing as a task
4. Identify task dependencies; they will represent communication as a white box. Identify to which task or goal in actor A this dependency is linked. If it is linked to a goal or to a task that is further decomposed represent this task/goal as a process in the lane for actor A and link it to the other lane (e.g. actor B) using appropriate messages.

Otherwise do the same representing as a task. Here it is also necessary to identify within actor B to which goal or task you will be linking actor A.

5. Rearrange the already represented tasks/processes to mirror the correct sequence of events if necessary.
6. Softgoals do not need mapping. Since in the ***i**** models we resolve softgoals to the point that achieve operationalizations to these softgoals, tasks representing these operationalizations will be automatically mapped while doing the preceding steps.

Figure 3 shows part of the process portrayed in Figure 2 mapped to BPMN.

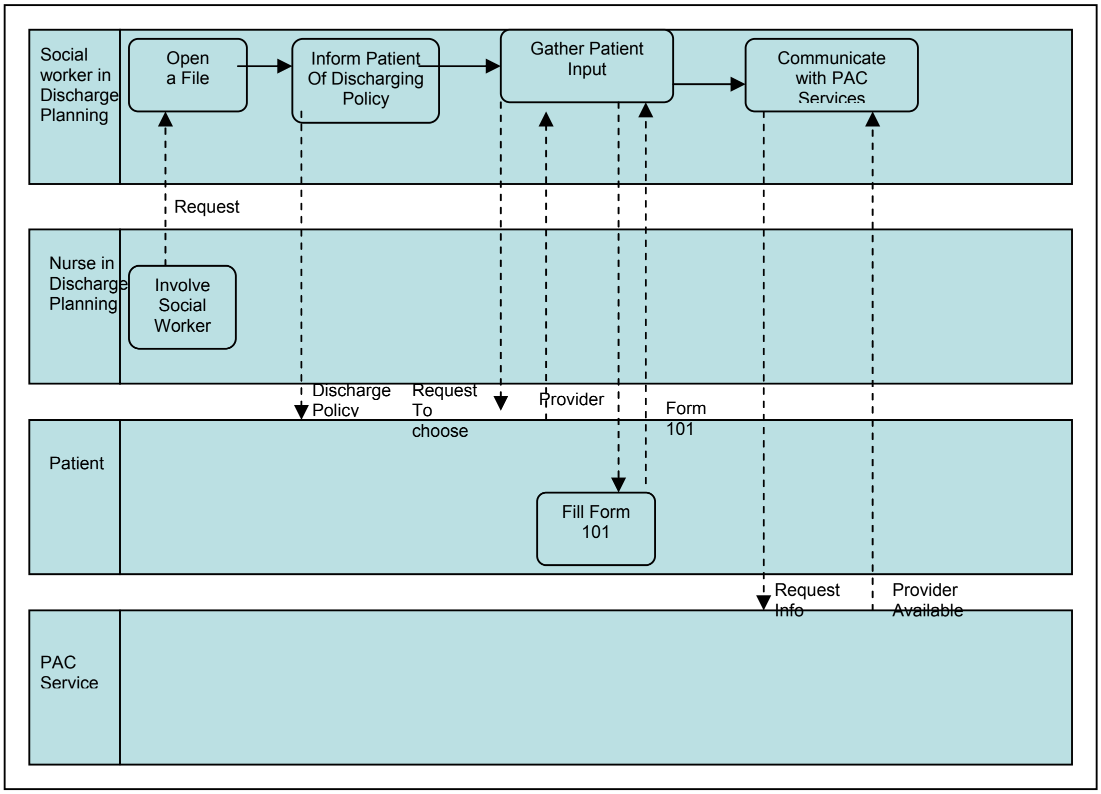

Figure 3 – A Example for Mapping i* into BPMN

4. Conclusion

This work argues for the need to represent and reason about agent autonomy in modeling and supporting business processes. We showed how to use the ***i**** framework to do that, recognizing that agents are allowed to pursue their goals in their own way, but also introducing constraints in the way some goals have to be achieved when necessary. Sequence of tasks can be expressed when needed [Liu 02]. A methodology presenting systematic guidelines to use ***i**** for requirements elicitation has been recently proposed [Cysneiros 03].

In order to diminish the gap between BPM and agent software paradigm, we propose to use the ***i**** framework as a front end to BPM techniques and languages. In such a way one should first use the ***i**** framework to understand the business and elicit requirements for the software-to-be. Once there is an established process suitable to all stakeholders, the process modelled in ***i**** may be mapped to BPMN [Owen 03]. Although this is future work, we have shown in section three a preliminary approach for this mapping. We also foresee that in the future, to cope with the need for flexibility, BPM may use software agents, in which case the use of ***i**** as a front end will be even more natural.

A version of ***i**** called GRL [GRL] is being proposed as part of a User Requirements Notation as a standard for the ITU Telecommunication Standardization Sector (ITU-T).

Future work includes studying how well the framework scales from small to very large systems.

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