Modelling Cooperative Work at a Medical Department

Full paper

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ABSTRACT
Based on ethnographic fieldwork, and the modelling of work processes at a medical department, this paper considers some of the opportunities and challenges involved in working with models in a complex work setting. The paper introduces a flexible modelling tool to CSCW, called the DCR Portal, and considers how it may be used to model complex work settings collaboratively. Further, the paper discusses how models created with the DCR portal may potentially play a key role in making a cooperative work ensemble appreciate, discuss and coordinate key interdependencies inherent to their cooperative work practices.

CCS CONCEPTS
K.4.3 [Organizational Impacts]: Computer-supported collaborative work

KEYWORDS
Models, Health Care, Ethnography, Cooperative Work, Formal Constructs

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1. INTRODUCTION
In this paper, an attempt is made to reach a better understanding of the role of formal organisational constructs such as models in cooperative work. Concretely, we take the complexity of cooperative work at a medical department as a starting point, and subsequently discuss the opportunities and challenges involved when modelling work processes at the department. Previous research has looked closely at the role of formal constructs e.g. models in organisational work [e.g. 3, 4, 9, 10], and they have focused on coordination mechanisms [4, 9], workflow management [3, 4], and have critiqued the ideas of Office Automation [8, 10-12]. This paper builds on these studies and explores the complexity of cooperative work practice at a hospital department and the challenges and opportunities for modelling that it poses. That is, we introduce a flexible modelling tool, called the DCR Portal, to a CSCW audience and consider how it may be used to model complex work settings collaboratively. Further, we discuss how models created with the DCR portal may potentially play an important part in making a cooperative work ensemble appreciate, discuss and coordinate their independencies.

Lucy Suchman's book "Plans and Situated Action" is a landmark in CSCW and often invoked when one wants to emphasize the situated and contingent nature of work practice [11]. This influential book juxtaposes the nature of practice in contrast to formal descriptions of action found in organisational constructs commonly referred to as plans. However, it would be a misrepresentation of the situated perspective to hold that formal constructs have no place or role to play in cooperative work practice [8]. As emphasised by Federico Cabitza & Carla Simone [4], formal organisational constructs such as plans or the models described in this article, are useful in a number of ways: (1) they are useful when dealing with recurrent and unproblematic situations (i.e. routine), (2) they are even useful in situations where plans are 'out of bounds,' because they can be used as a basis for improvisation and modification, and (3) the *process* of creating formal constructs such as models may play a key role in making a cooperative work ensemble appreciate, understand and recognise key interdependencies governing their cooperative work. Models may be for the good of cooperative work, then, as a means of coordination and as a channel of communication.

This paper discusses challenges and opportunities associated with modelling for coordination and communication purposes in a complex organisational setting, namely at a medical department in a large hospital. As indicated, it introduces a modelling tool based on DCR graphs (a modelling technique), and it discusses how this tool may be used in the context of understanding, describing and communicating cooperative work relations at the medical department in the form of models. It discusses challenges involved in doing so.

A key challenge associated with creating formal organisational constructs such as models is achieving flexibility. Flexibility has been a long-standing theme in the CSCW literature although it has rarely been defined; rather it has been thematised through empirical studies of work practice [4]. Some CSCW studies highlight how practitioners must be flexible in order to cope with unforeseen situations [7], other studies show that practitioners will create work-arounds to overcome rigidity of technology and procedures [2, 7]. The theme of flexibility is discussed in this paper in relation to the case of modelling the work processes at the medical department. To accommodate flexibility the modelling undertaken in this study is based on a constraint-based approach. The constraint-based approach follows the idea that one should only have to model the constraints (or rules) of a work process and then derive the possible action paths from these constraints.

Another well-know challenge is the users' unwillingness or inability to make the structures and procedures of cooperative work practice explicit [10]. This paper also speaks to this issue. Modelling allows, in our case, for the simulation of work process where several co-workers may play various roles and together simulate their cooperative work. This may help them recognise key interdependencies in their work and render them explicit in models.

Further, there is the question of who benefits from the modelling efforts, e.g. the issue that 'those that sow are not always those that reap'. Modelling techniques, and workflow systems in general, can be technologies for accountability, rather than technologies purely for coordination of cooperative work [3]. The complexity of grasping and modelling work practices is carried by one group of practitioners, while another group of practitioners may reap the main benefits and use the technology as a technology of accountability. This theme is also considered in the paper.

Having introduced the main themes of the paper, we are now in a position to introduce the modelling tool alluded to above, namely, *the DCR portal*.

1.1 The DCR portal

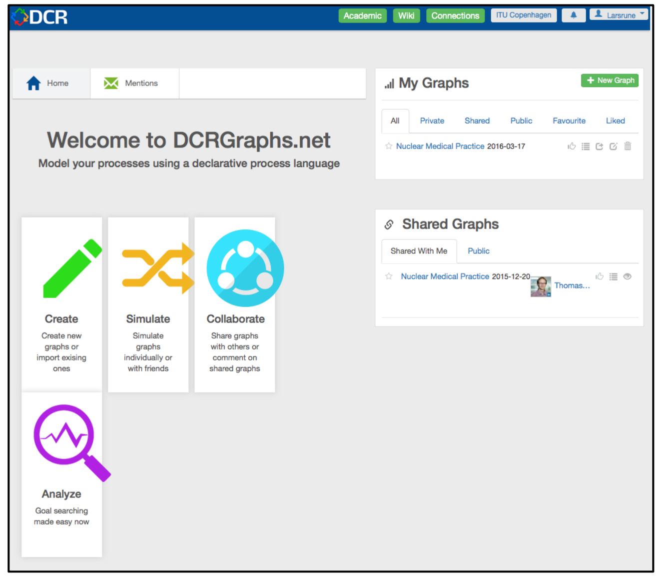

Figure 1. The front-page of the DCR portal running in an ordinary Internet browser

The DCR portal is a tool, available at dcrgraphs.net, with which end-users can create and simulate processes collaboratively. The portal is purely cloud-based, which means that it runs out of the box directly in a browser, with no installation or operating system requirements. The DCR-portal adds social media type features to modelling: Users can invite friends to the portal, send friendship requests to existing users, comment on models, browse models, and use an activity stream for discussing model design which supports on-going collaboration.

The principle behind the tool is to allow for a *constraint-based* approach to modelling work practice in the form of 'graphs'. A graph is a model that consists of an organised pattern of activities and their dependencies, as well as separate processes. In other words, a graph is a visualisation of a set of activities and their relation to one another. There are six types of relations available to the modeller as can be seen in Fig. 2 (we will give examples of these relations below in the section on modelling work practice at the medical department).

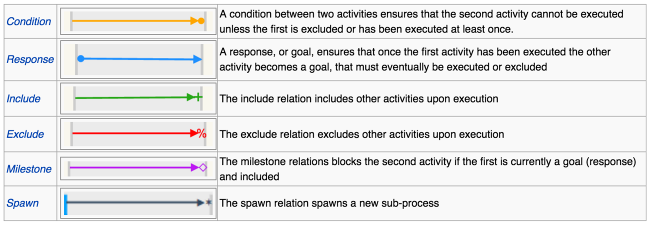

Figure 2. Types of relations within a DCR graph

A key feature is that DCR graphs or models can be simulated either by one person playing all the roles or by several people each playing some of the roles found in the graph. This enables users to obtain a better understanding of how the model works, simply by playing the model as a 'computer game'.

Furthermore, on the DCR portal, models may be searched in various ways: The Search Path feature makes it possible to search for paths to a specified goal that satisfies the constraints of the graph, similar to how one searches for routes using a GPS navigator. Dead-end analysis makes it possible to find potential paths that can lead to a state where the goal can never be reached, a deadlock that is.

In addition, major features of the DCR portal editor includes the ability to create new graphs, save and export graphs, edit existing graphs or import graphs to current graphs, a graph's revision history and the ability to show graphs as 'swim lanes'.[1]

Having made a general introduction to the paper and to the specifics of the modelling tool, we are now in a position to move forward. The paper will proceed as follows: First, we will describe the methods of the study. Second, we will introduce the setting of the medical department, and the work processes found there. Fourth, we will present a DCR model of processes at the department and discuss opportunities and challenges associated with modelling with the DCR portal. Fourth, we will discuss and consider the normative nature of formal constructs such as models. Finally, a conclusion is provided.

2. METHODS & SETTING

The empirical data was generated over a period of six months through fieldwork at a medical department at a large university hospital in Denmark. The fieldwork included observations of work practice at the department as well as 12 interviews. The data generation strategy involved following the workflow through the department. Conducting interviews and observations in all key units of the department, including the secretariat, the PET-CT examination units, the image interpretation room, the cyclotron unit, the synthesis lab and the drug quality test lab (we will return to these units below). During data generation and analysis, particular attention was paid to how different actors work in conjunction, and with time constraints, in order to perform their cooperative work tasks. Furthermore, the authors conducted a workshop with staff at the medical department to model the work process at the department with the DCR portal and discuss the challenges and opportunities involved.

As mentioned, the setting of the study is a medical department at a large hospital, the department is part of the diagnostic centre at the hospital. The department mainly performs diagnostics services for other clinical departments from both inside and outside the hospital. The department is highly specialized within the area of nuclear medicine. That is, at the department the focus is on medical imaging for diagnostic purposes using small amounts of radioactive material to diagnose a variety of diseases, including many types of cancers, heart disease, neurological disorders and other conditions. The practice of nuclear medicine at the department is a complex enterprise, which involves many different kinds of healthcare professionals, including physicians, nurses, bio-analysts, physicists and chemists who all contribute in their own unique way to the practice at the department (we will return to this below). The department has no patient ward as all patients come from other departments within the hospital as well as other hospitals and are only at the department for the duration of their examinations.

Positron emission tomography-computed tomography (PET-CT) is central in the diagnostic efforts at the department. It is best described as a medical imaging technique using a machine that combines both a positron emission tomography (PET) scanner and an x-ray computed tomography (CT) scanner. Images acquired from both techniques can be taken together, in the same session, and combined into a single superposed image. In this manner, imaging obtained by PET, which shows the spatial distribution of metabolic activity in the body, can be precisely aligned with x-ray imaging of the anatomy obtained by CT scanning. Such PET-CT images are central in especially the cancer patients' diagnostic processes.

[1] The second author and his associates have created the DCR portal in collaboration with Exformatics.

There are approximately 60,000 patient investigations annually and the department has a permanent staff of 125 healthcare professionals and hosts 25 PhD students.

We will now turn to describe work processes at the department with special attention to the activities, roles and time constraints of nuclear medicine in practice. These work processes will in turn be the objects of modelling efforts.

3. WORK PROCESSES AT THE DEPARTMENT

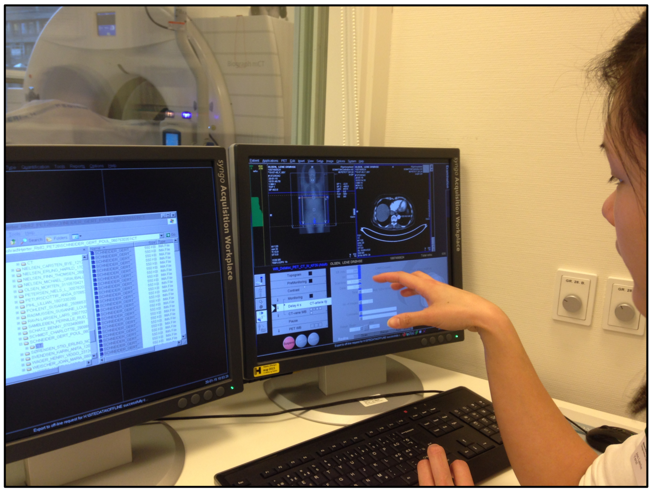

Figure 3. Inside the PET-CT control room. A bio-analyst is monitoring the process.

In brief, the diagnostic processes at the department involve the delivery of examination of patients using various forms of nuclear medicine. A precondition for the examination and diagnosis of the patients is the administration of them through various coordinative practices. As the department is specialized in diagnostics and has no ward, all patients are referred to the department. Referral basically means the transfer of a patient from a clinical unit outside the department to examination and diagnostics at the department. It is the secretaries and the physicians on call who handle the referrals on a daily basis. The refereeing unit typically specifies what kinds of examinations they are seeking for their patient, and the physician on call evaluates the referral and the examination asked for by the referring clinic. If the referral is deemed to be in order, it is passed on to the secretariat that schedules the examination of the patient, for example a PET-CT examination. At times, the physician may modify the referral in consultation with the referring clinic, but most often this is not the case and the patient is scheduled for examination by the secretaries on the basis of the approved referral.

On the day of the patient's PET-CT examination, for example, a bio-analyst injects a radioactive tracer into the patient's body – following a quality check of the tracer by the department's laboratory, and finally the patient's body is examined in the PET-CT scanner. The capacity of the five PET-CT scanners, as well as the other nuclear medicine equipment such as the three SPECT-CT scanners, largely dictates the capacity of the department to do patient examinations in relation to for example cancer patients. The PET-CT nuclear medicine imaging procedures are non-invasive with the exception of the infusion of radioactive tracers into the patient's body. Depending on the type of nuclear medicine exam, the radiotracer is either injected into the body, swallowed or inhaled as a gas, and eventually accumulates in the organ or area of the body being examined. A PET-CT imaging device then produces pictures and provides molecular information that represents radioactive emissions from the radiotracer (see Fig. 3).

The images of the patient's body produced by for example the PET-CT scanner are interpreted by the department's physicians who subsequently present the PET-CT images along with an interpretation to members of the referring clinic. In the conference, the future treatment and examination of the patient is discussed and decided upon.

Because nuclear medicine procedures are able to pinpoint molecular activity within the body, they offer the potential to identify disease in its earliest stages as well as a patient's immediate response to therapeutic interventions. For example, cancer patient's response to chemotherapy treatment is monitored using PET-CT technology and discussed in the conference. Are the chemotherapy drugs destroying the cancer cell? Can we see the tumour shrinking when comparing PET-CT scans of the tumour over time? The objective for the physicians is for example to identify when tumours in cancer patients improve ("respond"), stay the same ("stabilise") or worsen ("progress") during chemotherapy (see also [6]). Most of the patients being diagnosed at the department are cancer patients.

The images are ordered, distributed and displayed via a type of software suite referred to by its acronym PACS – Picture Archiving and Communication System. This is an imaging system that enables storage and access to images from for example the five PET-CT units at the department. The images are transmitted digitally via PACS. Non-image data, such as text, may be incorporated using digital document formats such as PDF.

Figure 4. In the synthesis lab, radioactive substances from the cyclotron are synthesised with biological agents.

PACS is connected to workstations where the clinicians of the department interpret and review the PET-CT images for diagnostic purposes. This process also incorporates a database for the storage and retrieval of the images and associated text.

A prerequisite for these examinations and diagnostic activities is the production of radioactive tracers at the department's cyclotron unit where the tracers are produced early in the morning before the start of the day. The radiopharmaceuticals (radioactive tracers) used for PET imaging are usually extremely short-lived. For example, the half-life of radioactive fluorine used to trace glucose metabolism (synthesized in a lab with glucose into FDG18) is only two hours. Its production requires a production line for the radiopharmaceuticals close by. The department has such a production line that includes a cyclotron unit, a synthesis lab and a quality test lab.

It is the cyclotron unit that produces the radioactive substances. A cyclotron works by accelerating particles outwards from the centre along a spiral path inside the unit. The particles are held to a spiral trajectory by a static magnetic field and accelerated by a rapidly varying electric field. At one point of operation, the accelerated particles are let out of their spiral path, out of the unit, forming a beam that endues whatever material is put in front of the beam with radioactivity. Such beam targets can be fluoride, but they can also be water or gasses. But the radiopharmaceuticals (tracers) need not only be radioactive, they also need to be somehow able to interact with the human body in order to register in a meaningful way on for example the PET/CT images. This is why the work in the cyclotron must be complemented with work in the chemical synthesis lab (see Fig. 4).

In the automated synthesis lab, the radioactive substance is synthesized with a biologically active agent. For example, radioactive fluorine-18 is incorporated into deoxyglucose producing the tracer FDG18. It is the glucose that makes the tracer register in the human body, it accumulates in the cells where the glucose is metabolised.

With a half-life of 110 minutes, FDG 18 is a rather short-lived radiopharmaceutical. The automated synthesis process in the tracer lab has the advantage of being rapid in face of the relatively short 110-minute half-life of substances such as fluoride-18. The automated tracer lab is preconfigured to handle the synthesis process and composed of several leaded compartments where the fluoride-18 and the deoxyglucose is synthesised and packaged. However, before the newly produced radiopharmaceuticals can be administered to the patients as part of their PET-CT examinations, the quality of the production batch in question has to be ascertained. One element that may vary some is the amount of alcohol used to suspend the fluoride-18 /glucose elements. The amount of ethanol used to suspend the tracer must not pass a certain threshold. The chemists in the quality assurance lab test this according to specified thresholds.

When the chemists have 'released' the tracers for use, then the bio-analysts in for example the PET-CT units may proceed and inject the tracers into the body of the patients in preparation for the PET-CT examination. The bio-analyst must draw the tracers from a leaded container and into a syringe. But before doing so, they must make sure that the dose is exactly right. This is done by calculation the dose measuring the radioactivity in the tracers with a Geiger counter just before drawing it into the syringe while at the same time adjusting the amount to the physical size of the patient.

Finally, every day before twelve o'clock noon the bio-analysts must order the tracers they need for the following day's examinations. This is calculated from the number of patients, the time of day of the examinations (due to the half-life of the tracers) and the type of examination (PET-CT or otherwise). The orders are handled using a web-based application called Tracer Shop that runs on tablets and desktops alike. It is according to the orders received in Tracer Shop that the physicists in the cyclotron unit plan the production of radioactive tracers. The production run has a set structure. In the case of the production of FDG18, the daily production run starts at 3:30 AM with the flushing of the system, the tuning of parameters and the acceleration of particles. Then the targets (e.g. fluoride, gas, water) receive beams of nuclear radiation between 4.10 AM and 6.25 AM. The synthesis (with e.g. glucose) takes place between 6:25 AM and 6:55 AM in the synthesis lab. Quality assurance takes place directly afterwards in the chemistry lab and the first batch of tracers may be ready for use as early as 8:30 AM.

Having provided a view of the work processes at the department, we are now in a position to move forward. We will now present a model of the processes at the department and discuss the opportunities and challenges associated with modelling these processes with DCR graph technique.

4. A MODEL OF WORK PROCESSES AT THE DEPARTMENT

The model depicted in Fig. 5 is a model of work processes at the department made using the DCR portal. It was developed in collaboration with the practitioners in the workshop organised by the authors. It represents a view of work processes at the department.

The practitioners may use the DCR portal in at least two ways: (1) to model work processes, and (2) to simulate and thereby demonstrate the model to colleagues prompting conversation and interaction. The two kinds of use may be interconnected as simulating the model with colleagues may lead to new insights that have a bearing on the model prompting its redesign – this can go on through multiple iterations until a satisfactory graph is attained. Up for discussion, for example, could be not only the order of work, but also the nature of the roles and responsibilities pointed out in the graph.

As mentioned, the DCR approach makes use of concept such as *activity* and role. A role owner is typically responsible for an activity and between the activities certain kinds of connections or dependencies can be modelled (see Fig. 2). For example, in Fig. 5 one of the roles is 'physician on call' and this role is responsible for the activity 'evaluating referrals', which is connected to the 'secretary' role responsible for the activity 'schedule examination'. The connections between the two activities are of the type 'condition' and the type 'response'. The type condition ensures that the second activity cannot be executed before the first has been executed, while the connection type response ensures that once the first activity has been executed the other activity must eventually be executed as well.

The usefulness of the graph technique comes to the fore when these kinds of simple relationships are tied together like a jigsaw puzzle forming the 'big picture' of what goes on in for example a medical department. At least, this is the promise or potential of the DCR graph technique. By modelling simple relationships and placing them one-by-one into the larger scheme of things, complexity can be depicted and eventually harnessed. For example, Fig. 5 is a composite of multiple roles (i.e. physician on call, secretary, bio-analyst, cyclotron unit, laboratory, synthesis unit, department physicians, physician from referring clinic), and activities (i.e. evaluate referral, modify referral, schedule examination, produce radioactive substance, synthesis, transport tracers to laboratory, quality check, inject radioactive tracer, PET-CT scan, interpret picture, conference, present picture, decide future treatment). These roles and activities are linked in the graph with various kinds of connections (i.e. Condition, Response, Include, Exclude, Milestone, Spawn).

A graph, then, consists of an organised pattern of activities and their dependencies. Typically, a role is defined as responsible for the execution of a particular activity. As indicated, activities can be linked together by connections to create dependencies of the kind seen in Fig. 2. An activity can represent the invocation of an operation, a step in a work process or an entire work process. Activities can be decomposed into sub activities if necessary as we can see in Fig. 5. We can for example see how the activity 'PET-CT examination' is decomposed into several sub activities, including 'inject radioactive tracer', 'PET-CT scan', 'interpret picture', and 'conference'. Some of these activates (i.e. 'inject radioactive tracer' and 'conference') are decomposed further. For instance, the activity 'inject radioactive tracer' is decomposed into 'make sure dose is right', 'draw tracer from container into syringe', and 'inject tracer'. All of the sub-activities within the larger activity of 'PET-CT scan' are as depicted in Fig. 5 as connected with a condition type connection. A condition type connection between two activities ensures that 'the second activity cannot be executed before the first has been executed'. This ensures for example that 'make sure dose is right' comes before 'draw tracer from container into syringe', with in turn must precede 'inject tracer'. These kinds of relationships are somewhat self-explanatory in this example, but in other situations with more complex relationships this may not be the case and this feature of condition types become more important. One opportunity here is to allow for such condition type relationships to be modelled step-by-step and fused into a whole, a model, that allows a group of users to overview their own processes. And subsequently discuss and coordinate them, and to simulate them with different dependencies and different role allocations.

In Fig. 5 we can also see the use of another type of connection, namely the response type. The response type connection holds that once an activity has been executed the connected activity *must* eventually be executed in turn. There is one such connection between for example the 'synthesis' activity of the larger 'production of tracer' activity and the 'quality check' activity. Such response type connections are useful when modelling for example safety critical connections between activities. In addition, response type connections are also useful when modelling time critical connections between activities. One rather abstract role depicted in the graph (Fig. 5) is the role of time. The response type connections between the activity 'new day' and the 'start of daily production' activity are first conditioned on more than zero examinations being scheduled, and secondly it is modelled so that at 4:10 in the morning, following 'new day', the 'start of daily production' *must* be initiated. In this manner, time constraints can be included in the model.

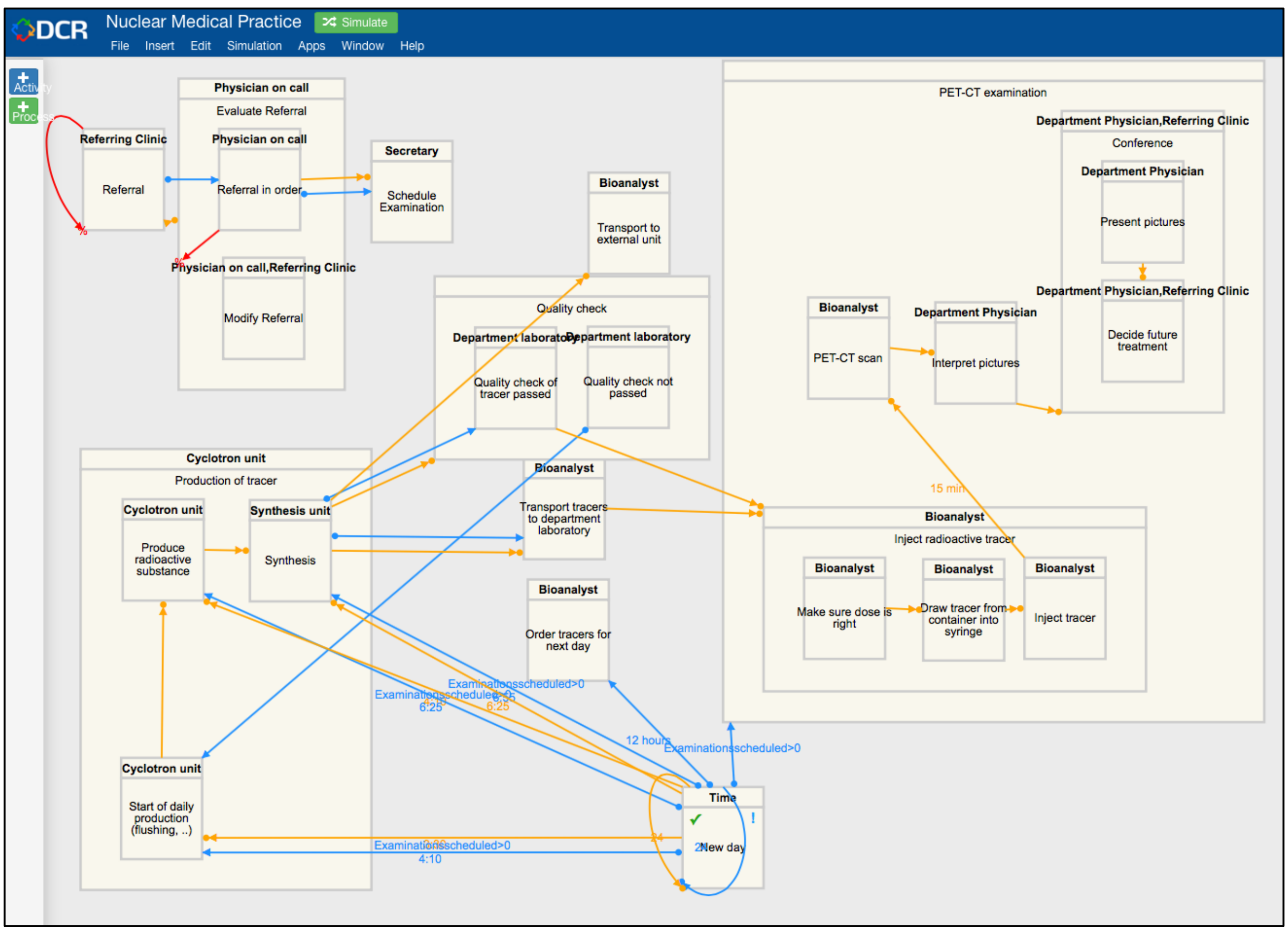

Figure 5. A model of work processes at the department of nuclear medicine

As indicated, the notion of roles is central to the DCR portal's simulation feature. Models can be simulated, either by one person playing all the roles or by several people each playing some of the roles found in the model. This enables users to obtain a better understanding of how the model works, simply by playing the model as a collaborative ‘computer game’.

When initiating a new simulation, one can assign a party to each of the roles of the model and these can be human or automated. For one person to simulate a model one has to leave all the roles assigned to oneself.

By inviting co-workers, one can start a collaborative simulation with different practitioners responsible for the different roles of the model. Two types of automated users are available. One has the character of an ‘eager user’ who will perform any available activity. The other type of automated user is known as a ‘lazy user’ who only does activities that are required. By assigning all roles to automated users, it is possible to run a fully automated simulation. Simulations can be paused and edited, and a record of each simulation is kept in the system for later replay. Activities that are enabled and have not been executed or are currently required are seen with a green frame that highlights them on-the-fly as the model is simulated. In this manner the progress of the simulation can be tracked. Another kind of progress tracking is provided by a list of tasks that shows all enabled or incomplete activities during the various steps of the simulation. Also on the list are the participants with their respective roles. Broadly speaking, the purpose of the simulation feature is to facilitate user engagement – both collaboratively and in single user situations. For example, when a team of co-workers states the constraints building a model and subsequently start a simulation they are giving themselves the opportunity to achieve a better understanding of their work processes and how they coordinate them. In this manner, the cooperative work ensemble can engage with the model, simulate it, and in the process articulate their interdependent work tasks.

Having accounted for work processes at the department and presented a DCR graph of them, we are now in a position to discuss the value of models for cooperative work. We suggest that they are best understood as normative constructs that can be good, or bade, for cooperative work.

5. MODELS ARE NORMATIVE CONSTRUCTS

The *normative* nature of models shows itself when we consider the way practitioners evaluate them in practice: What counts as e.g. a complete, incomplete, elegant, clumsy, clear or incomprehensible model is internal to the (formal and informal) standards of the practice. That is, the model is valued and evaluated based on criteria that are normative and internal to the practice that it is a part of. Usefulness is the keyword here.

A complex work process may be modelled in many different ways, even within the confines of for example the DCR portal. The question is not so much, which model is the most ‘correct and accurate’ one, but rather which model is the most useful one for the organisation. Let us elaborate.

Formal constructs such as e.g. models or plans are of a *normative* nature and their status as ‘useful’ or ‘complete’ is to be considered only in relation to a particular practice [5, 8]. For illustrative purposes, consider a plan such as for example a train schedule. It may be considered ‘complete’ if it provides, say, a full list of stops, timings, weekdays and holiday exceptions. It is obviously not ‘complete’ in the *absolute* sense of telling everybody exactly what to do (e.g. how to start the engines, signal, couple and uncouple carriages, get in and out of the train, and so on). It may be considered ‘complete’ in the *relative* sense of fulfilling the criteria, being in accord with norms internal to the practice of scheduling trains around tracks, norms held by *competent* members of the practice such as passengers and train conductors. In a similar manner, a model may be considered ‘complete’ and useful if it serves a purpose according to the norms of the practice, norms held by *competent* members of the practice. It may be considered ‘complete’ if it provides, say, a full overview of *pertinent* activities, roles and their interrelations. A model is rarely ‘complete’ in the *absolute* sense of telling everybody exactly what to do (e.g. how to draw fluid into a syringe, or how to start-up the cyclotron). In may be useful even though it may not specify each and every move of the practitioners, or each and every step of the process. Rather, there may be good reasons for not specifying every little detail, as we shall see.

Indeed, some of the details of the work process at the clinic are not visible in the model in Fig. 5. For example, the many constraints integral to the various half times of the radioactive tracers are not included in the model. Furthermore, the complexity of the production of the tracers is not modelled to include all the details of how that is related to the particulars of the nature of the scheduled examination. Different examination requires different tracers. For example, lung examination requires gases, while other types of examinations require fluid tracers. It is certainly an option to include these kinds of complexes in the model of work processes at the department. The DCR portal allows for it, and the 'production of tracers' could be modelled separately and linked into the parent graph using the DCR portals import model feature. And the different types of examinations and their scheduling could be linked to the production. The ability to add complexity to a model is from a technical standpoint close to limitless, but from a practical standpoint one must sometimes resist such urges and stop to consider the usefulness of adding more complexity to a model. Complexity can be overwhelming and hence counterproductive.

Time can be wasted discussing which model of a work practice is the most accurate or objective one. The discussion becomes far more fruitful when the discussion is based on the premise of usefulness. Which model is useful for planning and coordination purposes – that is the better question – when discussing several models or versions of a model representing work processes. This is as indicated related to the fact that models are best viewed as normative constructs rather than 'objective' representations of work processes. A model does not mirror reality in any monolithic or objective sense, nor should it strive to. Rather, a model represents a view of work processes that is hopefully useful for planning and coordination purposes. Egon Bittner wrote as early as 1965 that we must consider what plans inscribed in material artefacts "mean to, and how they are used by, persons who have to live with them from day to day" [1, p.242]. Again, what counts as for example a useful, or alternatively a useless model, is integral to the norms and the workings of the practice [5].

One challenge for the practitioners is not to be overwhelmed by complexity as they model, but to take it step-by-step. Another challenge for the practitioners, indeed for any person modelling, is to have sufficient overview of the practice to be able to know all key roles, activities and connections relevant to the modelling in question. This is yet another reason why the collaborative modelling approach, including the simulation feature, might be useful. It allows for the collaborative ensemble to contribute to the model collectively through sharing models via the portal and to meet and simulate the model by playing through the roles, activities and connections. In this manner, the partial and distributed knowledge of the work processes in a complex organisation such as a medical department may be shared, discussed and finally fused into an agreed upon understanding represented by the finished model. That is the potential at least. Of course, the understanding of processes as represented by the model may perhaps in some cases be continually contested rather than agreed upon. However, we have not encountered such cases in our work. This is perhaps because most organisations need some agreement, however tenuous, in order to be able to work as a functioning unit. In the case of the diagnostic nuclear medical clinic the points of contention, which the modelling process brought to the table, had the character of different points of emphasis rather than fundamental disagreement.

Formal organisational constructs such as the DCR models are useful in a number of ways. What is perhaps the most obvious potential, following the argumentation in this study, is the opportunity that the *process* of creating models can provide. That is, creating formal constructs such as models may play a key role in making a cooperative work ensemble appreciate, understand, and recognise key interdependencies governing their work. In the case of the DCR portal, we may say that the graphical interface, the sharing feature, and the collaborative simulation option play their respective parts in making this possible. The graphical interface arguably makes the DCR portal more accessible as a modelling tool to those not familiar with formal notations, the sharing of the graphs makes them available to teamwork, and the simulation feature makes the graphs open to tests and discussions of e.g. roles and responsibilities within a work ensemble. This provides flexibility. Alas, as indicated it can also provide a level of complexity that the untrained eye can have a hard time making sense of. In this manner, elegant flexible notations may lead to complex webs. This is a tension to be considered moving forward with this research.

6. CONCLUSION

For the sake of clarity, we will now briefly take stock and provide a conclusion.

This paper set out to address the fundamental challenge of characterising how formal organisational constructs such as models can benefit cooperative work. This agenda was addressed through the premise that formal organisational constructs, such as models, are useful for example in terms of dealing with routine situations, being a resource during contingencies and being a tool for reflection and coordination of cooperative work. Based on ethnographic fieldwork and the modelling of work processes at a medical department, the paper concretely discussed some of the opportunities and challenges involved in working with models in a complex setting. The opportunities included the ability to create and simulate work processes collaboratively through a modelling tool i.e. the DCR portal. These qualities may potentially play a key role in making a cooperative work ensemble appreciate, understand, recognise, discuss and coordinate key interdependencies of their cooperative work.

Furthermore, there is the issue of complexity. This is perhaps the fundamental challenge in at least two ways. First, there is the challenge for the practitioners in terms of having sufficient overview of the practice to be able to know all key activities, connections and roles relevant to the graph modelling in question. Second, there is the issue of not being overwhelmed by complexity as one builds the model, and as one considers the model in conversations and discussion with co-workers.

In addition, there is the challenge of motivation associated with the potential asymmetrical benefits i.e. who actually gains from the modelling, and for whom is it not directly beneficial. This is also a point to consider.

Finally, the premise for any qualified discussion of models and their role in cooperative work must be based on the firm realisation that such formal construct are of a normative nature. That is, their purpose is not to 'represent reality objectively', rather their objective is to be useful. Hence, usefulness should be the premise of any discussion of the role of models in cooperative work.

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