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HERDING CATS: OR MODEL-BASED ALIGNMENT OF HETEROGENEOUS PRACTICES

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Abstract

This paper reports on a study of how practitioners in engineering design try to develop and use models of the design space of the enterprise in support of collaborative work within global production networks. The paper also examines the difficulties they face in developing these models.

Keywords: engineering design, enterprise modelling, boundary objects,
1 INTRODUCTION

Ongoing changes in the global political economy seem to be accompanied by concomitant changes in the organization of cooperative work in enterprises and institutions. This transformation is, perhaps, particularly pronounced in manufacturing and engineering design.

For most of the 20th century, the activities of engineering design and production in manufacturing were typically organized within the framework of vertical corporations controlling more or less the entire process from extraction of materials to final product assembly and from design to production [4]. By contrast, the process is now — increasingly — ‘fragmented’, to use the expression adopted by economists studying the phenomenon [1; 5]. The pin manufacture described by Adam Smith has, so to speak, been taken apart and dispersed over specialized enterprises. Consequently, a large and steadily increasing part of (national and international) trade consists of trade in components (simple or composite) as opposed to final products. That is, on one hand the entire manufacturing process is now being distributed over multiple — sometimes thousands — of enterprises. On the other hand, the constitutive units become increasingly specialized. What emerge, then, are global production networks. The topologies may vary; some may look like ‘supply chains’, others like hierarchies of thousands of small enterprises controlled by a multi-national corporation, and others again like proper networks.

Many motives are at play in this transformation process. In many cases the driving motive is that of reducing the cost of labor by outsourcing to countries with substandard labor conditions. However, other motives, less transient and more sustainable, are also involved, such as the advantages of increased specialization, economy of scale, etc., made possible by plummeting costs of transportation and communication.

For a particular work organization this has the implication that it finds itself enmeshed in the middle of multiple networks. On one hand it produces components for a range of customers, often large corporations, and on the other hand it is itself a customer of a network of suppliers. When components are highly standardized items, commodities, this position is classic and does not pose a particular challenge. Nor does very stable ‘supply chains’ pose a major challenge to participants. The challenge arises and becomes a major one when component designs are not standardized and stable; that is, when customers request different and varying design configurations. The enterprise-in-the-net is then exposed to conflicting force fields. From its customers it is presented with requests and requirements with respect to its products that it will have to find economically viable solutions to: ‘Can we do this at all?’; ‘Do we have a design we can modify?’; ‘Do we have to open a new product line and could we then reuse the new design for other purposes in some modified form?’; and in any event: ‘What will it cost?’ and ‘Can we meet the schedule?’. And conversely, as far as its own suppliers are concerned, the enterprise-in-the-net of course poses the same requests and requirements. (New design options may of course flow in the opposite direction, ‘up stream’, just as legacy design options may disappear from the pallet, for instance for reasons of environmental protection).

In order to avoid that the enterprise-in-the-net, due to this situation, over time winds up in a swamp of proliferation of product models and variants that will completely neutralize the benefits of specialization and economy of scale, many enterprises-in-the-net are in the midst of developing a strategy centered on mapping out the design space, that is, the extant product portfolio, the design parameters for each product model (i.e., that which can be changed within economic reason), and the interdependencies of the different design parameters, e.g., ‘If you do this, then you also have to change that’. This conceptual structure is of course closely interconnected with the web of workflows that play out in the course of making design decision involving both in-house stakeholders and customers and suppliers. These are regulated by prescribed procedures and associated forms, schemes, etc.

All this is, of course, a cooperative effort of significant complexity, as it involves engineers, designers, production managers, marketing people, etc., who obviously represent different professions, different
organizational interests, different conceptual worlds, etc. This would in itself make such cooperative mapping effort of interest to CSCW. But not only that: it is an effort that in the eyes of practitioners themselves might benefit greatly by computer support based on computational representations of interdependencies of design decisions and design tasks, that is, computer support of a kind that is central to CSCW’s concerns. This issue was on the agenda of CSCW from the very start and has been pursued under labels such as ‘common information spaces’ and ‘organizational memory’. For good reasons much of this research has focused on the domain of technical design [cf., e.g. 6; 21; 22]. What is more, practitioners have, in a strictly experimental manner, actually begun building computational design space maps, or ‘models’ as they term it. In this paper we will report on a study of how practitioners struggle to do this.

We ground our arguments in extensive fieldwork carried out in three companies. We engaged with these companies as part of EU Project MAPPER, whose objective it was to develop, introduce, and evaluate an approach to ‘model-based adaptive product and process engineering’ in cooperation with three industrial partners in different European countries. Carparts is a supplier of automotive parts to major automobile manufacturers. It faces problems in managing myriads of highly interdependent tasks in a distributed network of suppliers. It also seeks to improve its ‘process of innovation’, in particular its collaboration with strategic suppliers. Finally, Digit, a very small enterprise producing digital components, is in the process of implementing and further developing tools in support of distributed design. In this paper we focus on Carparts.

We seek to understand in this paper how practitioners try to develop and use models in support of collaborative work within global production networks. We also examine the difficulties they face in producing models.

2 THE CASE

‘Model. Key word’

Before we go into the case, a few words on the very concept of ‘modeling’. It is a concept that is fundamental to engineering competencies but that is apt to mystify the uninitiated, as vividly described by Pepper White in his account of his miserable student years at MIT: When a teacher explains that ‘before you can control a system, you need to control the performance of a system’, but ‘once you know how to model things, you can model anything’, White, perplexed, thinks to himself, ‘Model. Model. Model. Eventually I’ll be able to use that word without blushing’ [24, p. 121 ff]. Ultimately, however, White begins to understand the concept: ‘Model. Key word. So an abstraction is like a model. And a model of a system may be composed of linked models of smaller systems, or subsystems’ (p. 218). — No surprise then that engineers, faced with the challenge of configurable design in production networks, would approach the problem as one in need of ‘modeling’.

While a ‘key word’ in engineering, the term ‘model’ is also a source of ambiguity in that different stakeholders use the words models and modeling differently. Models of different kinds in fact abound in the industrial world, typically engineering models, like structure and dynamics diagrams of organization, workflows, processes, products, etc. Professional ‘enterprise modelers’ on the other hand talk about singularly ‘powerful’ models in support of collaborative business networking, which they also consider ‘active models’. ‘Active models’ [14] represent operational data and shared actual knowledge, expressed by domain language artifacts and enterprise aspects. The units of these models are tasks, roles, products and parts of them. Modeling tasks or products is intended to capture the logical dependencies, express them in terms of complex parameterized relationships, and provide
visualizations of these dependencies and of different views of them. ‘Active models’ are to some extent executable (based on machine-controlled traversing of the dependency tree).

In the last fifteen years industrial ‘enterprise modeling’ has provided computer-supported visual models as consultancy tools for understanding and resolving complexity, in the area of manufacturing process modeling and simulation, as well as in the areas of enterprise architecture and governance, business process modeling, and enterprise performance analysis. ‘Enterprise modeling’ is seen as the art of representing the core knowledge of the enterprise [23]. However, up to now, modeling has not been an integral part of engineering practices, but is performed in isolation, by specialists. Executable models and modeling environments are detached from solution execution platforms. The situation is changing, however, with the stated goal of making ‘knowledge’ explicit in ways that make it accessible to business applications and users alike, for the purpose of for improving the ‘agility and performance’ of the enterprise. To this end, modelers have recently been endorsing what they term ‘enterprise visual scenes’ [15] where workers and players cooperate and interact. The modeling efforts we will describe belong to this movement.

Method

Empirical material was collected during two field visits, each of several days, in November 2005 and March 2006, with the purpose to help ensure that technical requirements be grounded in actual work practices and needs at the user site. During these field visits we had the opportunity, through ethnographic methods, to study a series of activities related to advanced engineering in the company. At our first visit we were able to observe how projects are managed. We followed co-located and distributed meetings, project meetings as well as design reviews and ongoing work at a series of workplaces in design, testing, and purchase. In our second visit we focused on interactions with suppliers and on the company’s ways of managing projects set up specifically for product and process innovation. Apart from this fieldwork, we engaged with various personnel groups in a series of interventions [Social Practice Design, cf. 12]: a workshop introducing engineers to a set of ‘creative design methods’, as well as two workshops with participants from design, testing, and material specifications that were convened with the aim of developing ‘visions of solutions’ to problems we identified in our fieldwork. Our final involvement with Carparts was a validation event in November 2007, where we, among other things, were exposed to an approach to product modeling which the internal project manager for MAPPER had developed. On that occasion, we also observed a modeling session dedicated to the creation of a model of collaboration with suppliers including a demo of model-support of customer-supplier design collaboration.

The long-term collaboration with personnel at Carparts (which was further strengthened in project meetings of all sorts) allowed us to acquire substantial knowledge of the ways of working in this company and its problems. But we also need to emphasize the limitations of our fieldwork with regard to the use of the modeling approach promoted by MAPPER. The models we will describe are constructed as part of experimentations and have not yet been deployed. They were developed over the course of almost one year by practitioners (in different professional and organizational roles) in collaboration with modelers (consultants, researchers, as well as in-house specialists in modeling). We were not able to actually observe the day-to-day process of modeling but rely on presentations of this process by the internal project manager. However, we have witnessed some the difficulties of those involved in producing these models and the numerous conflicts surrounding this process.

From ‘passive’ to ‘active’ documents

Producing car parts is a complex business, its design and production involving many distributed suppliers as well as numerous powerful customers. Coordinating with these different stakeholders is difficult. It involves, for example, creating ‘workspace awareness’ [10] during distributed design
meetings, establishing transparent communication about specifications with several suppliers, resolving the mapping problems between different part code naming standards, and so forth. Moreover, standards in manufacturing differ across national cultures. We have witnessed several meetings at which such differences created severe problems.

At present, managing this complexity leans heavily on documents that have been pre-defined for each project stage and that are meant to ensure ‘best practices’, as well as accountability. A key document in the hands of a project manager is the so-called ‘issue list’, which is central to handling the weekly project meetings. The form of an issue list ensures that issues are addressed in a particular way. The list specifies activities, responsible persons, and deadlines. Issues are identified by the number of the week in which they have been addressed and a short text. Issues are raised, defined, and entered in a collaborative fashion. The issue list provides a template for planning project activities and serves as a workspace when preparing and conducting meetings. The list also ensures accountability – commitments are specified and can be traced, as it is made transparent which week a decision on which issue was taken. We can say that the main function of the issue list is to document issues and the related decisions for awareness, reference, control, and accountability [11].

However, there are numerous problems with this ‘document-driven’ way of managing work. Although a document, such as the issue list, can contain links to other documents, it is not what in the ‘modeling community’ is considered an ‘active’ document, i.e., a computational artifact, that facilitates the updating and maintenance of the collection of documents or the triggering of some follow-up action. Furthermore, there is a host of documents ‘behind’ that needs to be aligned, updated, and shared within the production network. For example, much cross-checking has to happen in the process of negotiating specification parameters with several involved suppliers. To deal with this, Carparts has initiated the introduction of a document management tool (PLM), but the introduction is already delayed and has resulted in much frustration with what personnel at Carparts perceives as a pressure to produce more and more documents ‘for others’.

Carparts is experiencing particular problems with projects dedicated to product and process innovation. An example is a project that was undertaken in response to a EU directive on the restriction of hazardous substances, among them lead (2002/95/EC). After ten revisions of the project description, a consultant from a subsidiary was flown in to help develop ‘better ways of working’. He formulated his aim as: ‘We have to advance [a kind of] development which we can use for many customers globally; we need flexibility, and I would like to identify what could go wrong very early. We have to create new work methods’. Among his strategies were to create a ‘shared knowledge repository’ and to organize it around issues and design alternatives, evaluating and discussing the advantages and disadvantages of each solution. Also, to make the ‘design handbook’ accessible – ‘we want to use a good design – the handbook should be referred to in each design review, in each discussion’. The point here is that because of widely ramified interdependencies among design issues, a local design decision may have unknown but critical repercussions in another local context. Hence, evaluating design alternatives requires that one keeps track of all these repercussions. Also developing for a ‘global customer’ requires that issues of configurability are addressed, which we will return to later.

These two sets of problems – with the document-driven approach to managing complexity and with the process of innovation – form the background of what we will describe as the move towards ‘active’ documents - a ‘model-based company’.

3 PRODUCT MODELS AT CARPARTS

Product modeling was ‘discovered’ by users at Carparts as a result of cross-fertilization with another project. The models we describe are the outcome of a process that has been driven by the ‘use-case manager’ Paul. Finding the initial modeling sessions within MAPPER unsatisfactory, he was delighted when he came across a PhD thesis on product modeling for configurability in manufacturing: he
scrutinized every page and started producing small conceptual models, first with MS Excel, later with the MAPPER modeling tool. A small user group was set up, including a CAD technician and two interns, and began working, undertaking on average one modeling session per month.

The first example is a simple model of one of Carparts’ main products. The idea was to create a complex product description, decomposing the product into ‘configurable components’ (CC) as well as material ‘requirement components’, attaching to each of these components a set of validated variant parameters, product properties range, and interface requirements. Recounting the work of defining and agreeing on the parameters that define product variants, Paul describes how different stakeholders had different conceptions of modeling: ‘We have been spending a lot of time [trying] to identify what in the product variation should be modeled as a performance parameter, what should be modeled as a design parameter, what should be modeled as a constraint parameter, and what should be modeled as a variant parameter. And there were no real guidelines of what is what’.

The second example tells the story of a collaboration with an automobile manufacturer concerning facilities for the heating of car seats. In this case, product modeling helped to identify a gap in the available material and also demonstrated the need for modeling production. Paul has prepared this story as a MS Power Point presentation, which is his usual way not only of presenting ideas but also of co-developing them in conversations with others. Modeling the carrier material for one car part (identifying stretchability, environment friendliness, and cost as the main requirements, and polyester fabric and PUR foam versus polyester felt as the available materials) showed that there was a missing combination of properties and that Carparts might have found a carrier material they could sell, since none of its competitors uses it (Figure 1). As pointed out by Jack Goody in his study of the affordances of writing, ‘The table abhors a vacuum’ [8, p. 276].

The story goes on with the modeling of other components, such as the glue material and the heating wire. For the latter, the heating wire, requirements or properties (electrical, mechanical, failure modes, cost), design parameters (conductor material, thickness of strands, surface layer, fiber reinforcement) were defined, and the option of serial versus parallel circuits was identified as an additional parameter influencing the choice.
The outcome of this conceptual modeling exercise is illustrated in Figure 2. In this case the choice was between sinus wires and alloyed wires: “With a free product model configuration, then, it would recommend very thin copper strands, because of the price, and if we add the mechanical requirements then it would be fiber reinforcement. ... but in reality we are using these HFA, the alloyed wires, because [of] the constraints in production: the wire layout with the fiber enforcement wire is not doable. And if you add in PVC and insulated wire then there are constraints in peeling insulated wires; so then you will damage the wire. So this was why we say that the configuring of product should be extended also to configuring the production’ (Paul). Our third example is to do with a problem Carparts had in a customer project with the specifications of a particular component. There was a failure on the side of Carparts in communicating certain material specifications to one of its suppliers, which had several repercussions. Paul used this example to propose a model that captures the status of requirement specifications with different suppliers.
As can be seen in Figure 3, the model also includes the customer and supplier business agreements. Paul comments: ‘This is an important lesson for the product modeling [effort]. If we don’t catch the product requirement, then we will not catch the business agreement either. Once it comes to things, once it appears false in the deliveries, then you must know whom to blame. And these specifications are the base for [deciding] whom to blame. So I mean, if we have a better specification of the products, then we are safe in our business agreement.’ The idea is that by means of such a model, alarms for missing requirements could be generated.

These conceptual models are ‘on paper’ or exist as MS Power Point presentations or have been modeled by means of the MAPPER tool. Common to them is that they are not executable. However, we saw a demo of another model with a small executable part that practitioners at Carparts had prepared to support collaboration with suppliers. The scenario was the following: Jane, the responsible for material specifications at Carparts, opens the graphical workspace of the modeling tool, searches for a specific wire and enters a specification for resistivity. As a result, the customer responsible at E-Supplies is notified; he edits his own specifications in his own Excel file, and Jane then receives and reviews the result. In this way a specification document is built, turn by turn, both parties seeing exactly the same data while the ‘secrets’ of each party (ownership of data and formulas) are safeguarded. In this scenario the responsible for a specific family of materials can also see the aggregated values and compare them to the customer request).

4 EXPERIENCES WITH MODELING

The immediate experiences with modeling at Carparts were mixed. We found that ‘common’ users at Carparts are not convinced of the value of conceptual modeling, but then they have not had a chance of developing an understanding of this approach, in particular of the need to make informed choices and reflect on their implications, and of how a model may productively interact with work practices.

On the other hand, at the validation event the simple executable model facilitating cooperation between roles (and between Carparts and its suppliers) was perceived as a good checklist: ‘you can see the status [of the specifications] and can highlight the risks from the beginning’. Users were not only interested in adding more details to the model but pointed to the value of implementing design rules – ‘there are so many rules around wires – so as to be able to replace the [spreadsheet] tools we are working with now’. They could also imagine using the model for prioritizing sales options: ‘sales is very impatient, even for early quotations; if they have the tool they could see for themselves ...’.

Thus, as part of a modeling session users compiled a small list of expected benefits. These include: faster decisions and faster communication within Carparts as well as with suppliers, reduced lead time, increased mutual understanding of internal processes on both parts, avoidance of redundant working and thus reduced costs, but also improved creativity (e.g. identifying new types of wire).

Overall, the entire process of modeling at Carparts has had the character of experimentation. For example, the experience by practitioners at Carparts that modeling involves a systematic conceptualization of a problem was the result of cross-fertilization with another project and thus rather fortuitous. Similarly, practitioners observed that product models not only represent physical components and their relationships but that they can and need to be extended to include parameters concerning organization, contract, and so forth, that is, issues of assigning responsibility and establishing trust.

Anyway, the aim of this paper is not to report on specific experiences with the MAPPER modeling tool or on experiences with the executable enterprise models they support the construction of. That would be premature, given the highly experimental setup. What has become evident in the process so far, however, are some characteristics of modeling interdependencies in cooperative work settings that are both important and of general interest.
The troubles of Herding cats

One of the key issues in our findings is to do with the fact that the small kernels of possible future enterprise models build on modeling interconnected but heterogeneous practices. CSCW research has quite early pointed out that ‘the cooperative ensemble reproduces the multiplicity of its environment in the form of the multiplicity of ‘small worlds’ of professions and specialities’ [19, p. 6]. Hence the challenge of bringing multiple, incommensurate perspectives together.

What we observe is that identifying the relevant parameters, and agreeing on them, pose a major challenge. The issue, we find, is that selecting parameters depends on the particular perspective users assume and the context for which it is needed: ‘there is no best model’. In the sciences and in engineering, modeling is a (typically quite systematic, sometimes rigorous) procedure of abstraction for creating useful representations of aspects or sections of the world. It is purposive, therefore internal to a specific practice. No model of a given section of the world is ‘true’ or ‘false’ in splendid isolation from the practices to which it belongs. Rather, models are ‘useful for the purpose’, or ‘not so useful’, as the case may be. — ‘Useful for the purpose’, but for which purpose? Different practices (e.g., concerning production and procurement of insulation, wiring, adhesives, fibers, as well as sales) are characterized by different concerns; they address different aspects or sections of the world with different structural and dynamical characteristics, and they thus conceive of the world differently, apply different criteria of importance, success and failure, etc. Consequently, when it comes to modeling, practitioners of different branches of engineering design have different perspectives that in turn indicate a notion of central object or ‘unit of analysis’ as well as criteria of what to ‘foreground’ and ‘background’ in modeling.

Moreover, even within a given perspective, relevant trade-offs dictate preferences in modeling commitments. The top level trade-off is ‘what’ in the entire world to include or not include in the model’s explicit representation, depending on the costs of handling (gathering, eliciting, validating, maintaining) the requisite information in the model, versus the advantages gained by using the model. Other crucial trade-offs exist in structuring the model, especially in the choice of level of ‘granularity’ (level of detail) and of ‘specialization’ (depth first) versus ‘multiplicity’ (breath first). This issue applies to task bundles as well as to product models.

Practitioners at Carparts (as well as in the two other companies we studied) are well aware of these challenges. The models we describe in this paper are the result of many trials and people involved in these trials describe the difficulties of first finding an ‘angle’ on modeling, that is, whether to model task bundles, the product, design alternatives. They stress how difficult it is for a team involving different specialities to identify the relevant parameters and agree on their definition. As Paul described this incommensurability that is so hard to resolve: ‘where he [a modeler] used variant parameters, he should have been using performance parameters’, and so forth. What seems already difficult in a small team involving 2-3 different perspectives can grow into a nightmare when one takes into account the vision ‘the same idea and principle can be used for our customers as well, and also our neighbors, interface suppliers; they can use the same. So that is the very good thing with these configurable components. You can use it at every system level’. The issue of ‘granularity’ of modeling is confounded by the heterogeneous practices. For example, addressing the question of how many configurable components to define and on which grounds to decide this, Paul observed that a supplier has other ideas about what to maintain as configurable than has a car manufacturer, for whom it is the car part as a whole that is of interest. The chosen level of granularity also depends on where Carparts thinks they can innovate, or where they think one of their suppliers could contribute something novel, e.g. a lead–free component, a particular technique.

All these decisions are by no means arbitrary, but they become exceedingly difficult when multiple perspectives are involved.
Only fools rush in

From the beginning, it was Paul’s conviction that a ‘theory’ of what was to be modeled, that is, of the design space of the company, was needed, but due to the lack of such a theory he decided to start with the smallest component: ‘What we are doing now ... is to dig into the detail, the very detail of our product. And this modest thing is the conductor or the strains of our heating wire, and then to build it up ...’.

In the course of the project, practitioners at Carparts came to favor a bottom-up approach to modeling, starting with simple tools and simple modeling tasks, in order to be able to engage users of the modeling tool in the process. They emphasized that it makes no sense ‘to push for modeling’ unless such a systematic conceptualization has been achieved within the organization in a participatory way.

Consequently, they expressed the value of passive or non-executable models for the organization: ‘And the target for [the modeling consultancy firm] has always been executable models; we also see it as the final target. But also non-executable models like the one we had produced ... you can learn a lot from non-executable models also, because [building them] drives the discussions, you can say. You have to ask yourself a lot of questions to produce that model. By asking yourself these questions you are learning. Or you structure your knowledge’.

However, existing modeling tools offer only inadequate support of the participatory process of building a conceptualization of design spaces. What we observed is that the three companies had completely different starting points in creating models: scenarios, activity diagrams, workflow descriptions. Modelers responded to these familiar representational formats by introducing a set of ‘templates’ that offer a particular notation and a library of objects and relationships that have been predefined in a ‘meta model’: ‘the specification work can be significantly be significantly reduced by describing the manufacturing or logistics system by a re-useable template, and store it within a library for later use […] Structuring] the templates in an object oriented class structure saves modelling effort and at the same time supports additional transparency as well as some standardisation’ [17]. Behind the ‘templates’ are different ‘approaches’, such as POPS (Process, Organization, Process and System), ICOM (Input, Constraint, Output, Mechanism) and CPPD (Collaborative Product and Process Design), For an informative review of ‘process modeling languages’, cf. [16]).

The choice of template obviously determines what kinds of relationships (hence perspectives) that can be modeled (hence expressed). For example, during a modeling session at Digit the modeler explained: ‘Part of planning and setting up a modeling environment is to select the right kind of modeling template, the right kind of modeling languages. But [most] likely, since you can add new things later, depending on the needs as they arise, it is rather flexible as well. You can start modeling using simple templates and add as things go along’. Choices were formulated in terms of template names, such as ‘in this case I think we will use ITM or BPM’ or ‘so should use a BPM template and not a CPPD template’.

What we observed in our case, however, was that tools and modeling practices did not support the conceptual work that Paul, on his own initiative, started at Carparts, that is, they did not support the tedious work of thinking of a product in terms of configurable components, variant or design parameters, and to do this from multiple perspectives, step-by-step discovering the benefits of the model for distributed engineering in large scale production networks.

There was observably a rush towards implementation and generation of results that made modelers somewhat inattentive to the basic necessity of establishing the foundations, in terms of systematic conceptualization, modeling competencies, new practices, etc.

Grinner [9], in a study of a successful configuration management system, points to three reasons for its success: systems developers (in her case) understood and accepted the model of work implemented in the CMS (which for example led them to accept a bug tracking system that posed some constraints);
representations were understandable and useful — the developers could trust what the system was telling them about the current development state; and the ‘right’ work was automated.

Our argument is similarly that for modeling to be productive, users need to be able to develop a deep understanding of the models and that the tool itself has to support building models and experimenting with them so as to develop well grounded abstractions.

Whence the rush? We have no way of answering the question. But some explanations seem likely. Firstly and obviously, there is the competitive pressure that permeates everything that goes on in manufacturing and engineering design. It may, on the ground, foster irrational behavior and unsustainable solutions, but it is institutionalized in budgets, in annual and quarterly targets, in performance measurement systems, etc. But there is also a certain ethos in the engineering approach to modeling which was nicely expressed when Pepper White’s teacher said that ‘once you know how to model things, you can model anything. It does not matter whether it’s a mechanical, fluid, thermal, chemical, electrical, or biological system. The concepts of modeling are the same’ [24, p. 122]. Given such an approach, rushing in would be the norm. It would also make one inattentive to the incommensurate conceptualizations of, say mechanical, electrical, and organizational systems.

This rather rash approach to modeling is also reflected in the observable proclivity to extend the object of modeling from the factual (e.g., work processes and products) to the not so factual (e.g., contractual arrangements, trust, knowledge). And then from static object structures to evolutionary dynamics, assuming causal dependencies in people’s actions and disregarding intentions, encountering vast opportunities for disaster.

Asking for the moon

When visiting Cuba shortly after the revolution, Jean-Paul Sartre had a conversation with Fidel Castro. At one point in the conversation Castro said that the revolution would get people whatever they requested, to which Sartre raised the sensible question: ‘What if they asked for the moon?’ Castro thought for a moment and replied: ‘We may not be able to get it for them, but we would understand that they need it.’ [18]

When workers at Carparts, Newcars, Digit, and many other enterprises are engaged in developing and tentatively pursuing a strategy of constructing computational models of the enterprise–wide design space, in order to find a way of coordinating internally and with other enterprises in global production networks, they may indeed be ‘asking for the moon’. What they do may eventually turn out to be impossible but that does not discount the obvious need.

Trying to meet the different and varying requests and requirements of their large customers in the automobile industry and at the same time trying to sort out their network of suppliers, the practitioners at Carparts are engaged in a very demanding exercise. The received ways of doing this, relying on a network of (passive) documents and a flow of documents is seen as increasingly inadequate. They need ‘active documents’, that is, facilities that can automate their work of keeping track of design interdependencies.

These conceptual and practical problems exemplify what Bittner [2], in his brilliant essay ‘The concept of organization’, wrote about organizational rules, arguing that the sense of a organizational rule (and, a fortiori, a model) is relative to the practice for which it has been devised. This is reflected in his suggestion to ‘attain a grasp of the meaning of the rules as common-sense constructs from the perspective of those persons who promulgate and live with them’ [p. 251]. Interestingly he refers to the role of organizational rules in linking affiliations between entities (people, tasks, parts of a complex product, and so forth) that ‘are too remote for contingent arrangement’. Organizational rules help people link those entities into ‘coherent maps or schedules’ where ‘each link derives its meaning not so much from the specific rule that determines it, but from the entire order of which the rule itself is a part’ [p. 252]. That is, organizational rules (or models) are constructs members of a particular
organizational unit or profession define in order to connect with elements that are outside the scope of their own direct influence. How these rules are understood and evoked depends on the situation, practice, and perspective of the involved actors. With this argument Bittner points to the fundamental ambiguity and openness of rules but also to their power in linking things that are remote — geographically and socially, but also conceptually.

A way to conceptualize the specifics of the kind of budding practice we have observed would be to discuss it under the perspective of the concept of ‘boundary objects’ [20]. This term was introduced and is being used to denote artifacts that, at the boundary between different local practices, facilitate loosely coupled collaboration between these communities. In the words of Bowker and Star: ‘Boundary objects are those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. Boundary objects are thus both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual-site use.’ [3]

The models under tentative construction at Carparts were obviously conceived of as something akin to boundary objects, in as much as the models were deliberately designed to be far less detailed than the CAD models of products and parts already in use. Practitioners at Carparts and modelers thus made an interesting distinction between CAD drawings and product models. The product model provides a simplified view of each part of the product, hiding much of its complexity. Contextual knowledge can be added, as well as information on pending issues and on related tasks and responsibilities. That is, each model is not just a drawing; it has property sets.

However, the models with which practitioners were experimenting were of course not yet boundary objects. They are rather objects serving negotiations and learning across boundaries [cf. 13].

Anyway, whatever their current status, what workers at Carparts are trying to construct goes beyond boundary objects in that the product model is obviously intended to regulate local action in a rather strong sense. This, then, poses the problem they are struggling with: they are trying to construct one integrated and overarching model for heterogeneous practices, not a family of related models representing different perspectives. In other words, what they are up against is that representations are local and temporary closures [7].

![Figure 5: Paul’s vision of overarching product models](image-url)
Now, building one integrated and overarching model may very well be the only viable approach. But it might just as well be a prejudice, if not on the part of practitioners at Carparts, then a prejudice on the part of developers of notations and tools of modeling. That is, perhaps a family of related models would be more feasible: more appropriate for a bottom-up process of model construction; more appropriate for involving, expressing, integrating multiple perspectives.

Modelers within MAPPER were principally aware of these problems but they were also convinced that they had the right approach to addressing them in efficient ways, such as a modeler at Newcars who talked of his approach as a war room: 'The idea is that for each wall of this room you have different models representing different domains. You have an expert for each of these walls and when you are in the middle, you just can give a look to all these models and try to see the connections between process and organization, product and system'.

While articulating acute awareness that a multiplicity of models is required, this proposal also, albeit implicitly, demonstrates that current modeling technologies are deficient when it comes to expressing the relatedness of perspectives and thus supporting the interconnectedness of heterogeneous practices and leaves it to practitioners to figure that out themselves, as they have always done.

Existing technologies of modeling are very flexible when it comes to building models in a piecemeal fashion and then connecting them, just as they offer the flexibility of choosing different modeling approaches and notations. However, the current modeling environments are lacking when it comes to expressing the relatedness of models from different perspectives.

That is, there is definitely a room for CSCW research to fill this gap between monolithic models and disconnected models. In fact, there is not only a room, there is a need.

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