Participative Process Modelling

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Abstract

This paper motivates and illustrates a new approach to providing computer support for participative modelling of processes, and for modelling participative processes. This approach relies upon constructing computer-based artefacts that serve an explanatory role. The construction of such artefacts proceeds in a distributed and incremental fashion in association with the development of a working understanding amongst the participants engaged in process comprehension and design.

1 Introduction

Modelling processes is a crucial part of the understanding and design of systems. This paper describes a new approach to providing computer support for process modelling, where the emphasis is on constructing artefacts that can serve an explanatory role similar to that of the physical models an experimental scientist might construct to represent their provisional knowledge of a phenomenon [2]. Interaction with such artefacts in a distributed environment provides a form of participative process modelling that is well-suited for collaborative comprehension or design. The paper is in two sections. The first is motivational in character. The second illustrates our key principles and techniques with reference to the processes associated with warehouse operation.

2 Participative Process Modelling

Participative process modelling can be interpreted in two ways: as *modelling of participative processes*, or as *participative modelling of processes*. Throughout this paper, the term *process* will be used to refer to generic sequences of state changes that follow a well-defined and reliable pattern. In thinking about how such processes are conceived, especially in a business setting where there are both human and automated actions, two different kinds of agency are typically invoked. There are the *internal* agents that enact the process itself and are deemed to be responsible for state change, to whose interaction the term 'participative process' refers. There are also the *external* agents whose comprehension of the observed interactions within a process gives it its integrity and well-specified character. In-depth comprehension of a process is a task that relies upon integrating many agent viewpoints, an activity to which the term 'participative modelling' refers. The participation of both internal and external agents can be active or passive to a different degree. The interactions of internal agents may be governed by strict rules, perhaps to such an extent that their autonomy is at issue. The external agents may be responsible for designing or managing the process, or may simply act in the role of the observers of a natural phenomenon.

The semantic categories associated with internal and external agency, processes and participative activity are not sharply defined. This can be illustrated in many ways. The actions of an agent within a process may reflect both internal and external perspectives at one and the same time. It is unclear to what extent it is appropriate to regard the observer of a natural phenomenon or an automatic device as 'participating'. The coherence, reliability and integrity that are the defining characteristics of a process may be subjective, and so be appreciated by one agent rather than another. Contemporary applications and aspirations for computing tend to make it ever more difficult to sustain clear semantic distinctions. Consider, for instance, the different character of the computer support that is required for processes associated with chemical engineering, computer-assisted learning, or software engineering, and the nature of the agency and participation that these involve.

In its most narrow sense, process has been central to computer science. Classical computer programming is framed with reference to regular patterns and preconceived interactions serving a particular goal. Agency is subdued in this setting, for state-changing activity typically conforms to a pre-ordained scheme. Some of the most successful business applications of computing involve the use of relational databases to record the routine transactions of exceptionally well-defined processes. Such applications are consonant with a rationalist perspective on administrative,

scientific and cultural affairs, which seeks to explain processes with reference to what is so reliably and commonly experienced that it admits a symbolic representation. There are arguably corporate activities that cannot be dealt with satisfactorily in this manner, in which interaction cannot be framed solely in terms of shared symbols, but must refer to the richer subjective observables of the individual participants. This has become evident in the modern role for computer-based technology, which involves more than bookkeeping for formalised human interactions, and addresses applications where the extent to which automation is possible has yet to be established.

This paper adopts an alternative perspective on computer use. It is primarily concerned with constructing computer-based models to support the activities surrounding the identification of processes. Modelling of this nature has to engage with knowledge that is neither objective nor clearly articulated, and confront the rich and potentially confusing differences between agent perspectives that this entails. A central issue is the relation between actions that are circumscribed by rules and the situated actions encountered in everyday experience, where we have to address unprecedented problems, engage in interactions of a serendipitous and creative nature, and isolate the cues for process interaction from a world where sensation can be overwhelming and action unconstrained. This agenda is relevant to many aspects of business processes. For instance, it relates to training (disentangling the aspects of a situation that are specific to role and purpose from the general apprehension of situation), and to the subjective nature of each employee's capabilities (accounting for the fact that we typically expect personnel to perform duties to different levels of competence and with different degrees of initiative subject to their experience and insight, sometimes in the absence of clearly specified rules). A major consideration is disclosing the tacit assumptions and contextual factors that underlie the successful execution of business processes. This is relevant both to business process comprehension and to design of alternative mechanisms and protocols in business process re-engineering.

Our understanding of activities such as bird migration helps to illustrate key issues involved in constructing suitable computer-based models. There is a clear distinction between an external view of migration, as expressed through knowledge of the times of year at which a particular species migrates and the destinations to which it flies, and "internal" insight into how this migration occurs. Though migration is comprehended as a flock behaviour, it is not attributed to the action of an external superagent, but to stimulus-response patterns governing the individual birds. A satisfactory account of migration is more than knowing what pattern is followed in migration activity – it also demands insight into mechanisms. A possible explanation can be framed in terms of the responses of birds to magnetic fields, even though such a response is outside the scope of direct human experience. As Gooding discusses in detail in [2], physical models that can potentially be constructed using computer technology play a very significant role in supporting such explanations. The sophisticated experience and observation of our environment that leads us to the concept of electromagnetism is mediated through physical embodiment of similar experience in such artefacts. The quality of an explanation based on such an indirect representation of experience is assessed by its descriptive and predictive value.

A parallel can be drawn between our interpretation of migration and that of business processes. For instance, in the warehouse case study to be discussed in the next section, the formal interactions that are documented in filling and distributing paper forms represent an external objective account of the processes. The warehouse example has the merit that the participants are human, so that we can hope to understand their perceptions and responses to a greater extent. It is clear that form processing is merely witnessing to the real activity of the warehouse, which involves the physical movement of items, the observation of their location, and the monitoring of their status. Whereas the processing of forms is abstract, and can be enacted in isolation from authentic warehouse operation, the real activity is essentially situated, and is associated with an exceedingly rich and complex perception of many aspects of the current state. Internal insight into the warehouse operation requires an account of each worker's activity that is rooted in their direct personal experience of their working environment, and adopts a perspective that acknowledges their true role as an agent of change. These considerations frame the kind of computer-based modelling of processes that is needed for comprehension and re-engineering, viz. participative modelling in which the aim is to develop a suitably convincing computer-based representation for the state-as-experienced of each internal and external participant.

3 A Case Study in Empirical Modelling

Our approach to computer-based modelling will be illustrated with reference to work in progress on modelling the processes of warehouse operation (cf. [1]). The principles and methods behind this approach arise out of a broad and unconventional approach to computing which has been the

subject of research at the University of Warwick for many years (so-called 'Empirical Modelling', see http://www.dcs.warwick.ac.uk/modelling). As a modelling method it is unusual in being close in spirit to human, cognitive modelling and yet being computer-based. The initial analysis of a domain is made by identifying *observables* considered relevant by the modeller. These are then grouped around *agents* (including human agents) regarded as able to instigate change in some of the observables. The other essential source of change comes from *dependencies* holding between observables and expressed in *definitions*. These are 'law-like' dependencies such as Newton's law, or the rules stating when a game is won. A set of definitions – a *definitive script* – corresponds to a single state of the model. Any particular state of the model should directly correspond with a meaningful state of its external referent. The script of a model serves as the basis for an exceedingly rich state-transition model in which transitions are associated with re-definitions or new definitions. A single re-definition may trigger the automatic updating of many other variables. Groups of re-definitions may be bundled together as the action of an agent. There is great flexibility for the developer, or modeller, to delegate an action to an automated agent, or introduce definitions in a potentially arbitrary and unrestricted fashion. During the course of model development it is likely that new observables, dependencies and agents will arise apart from those initially expected. These new perceptions are the product of experimentation with the model and give insights to the user. In this way the process of model building proceeds in tandem with the enrichment of the user's own conceptual model of the domain. The scripts we build may contain explicit propositional knowledge but the rich interaction possible with the artefact represented by such a script offers the engaged user experiential and tacit knowledge of the domain. Our tools support the concurrent participation of several users.

3.1 Representing State in the Warehouse

The principal innovation in EM is in the construction of computer-based artefacts that serve an explanatory role. The state of each such artefact is specified by a definitive script, and is intended to represent the current state of its referent, as viewed by a particular internal or external agent. It is typically appropriate to network many such artefacts and to establish dependencies and interactions amongst them so as to reflect the manner in which agent views are related. For the warehouse, the relevant internal agents include foremen, warehouse workers, forklift operators, office personnel and truck drivers, whilst possible external agents include an omniscient global observer who is presumed to be able to witness all the movement and interaction within the warehouse, or an auditor whose task is to trace transactions. As discussed above, a strict separation of such roles is inappropriate. For instance, the forklift operator maintains a global sense of the layout of the warehouse and – quite reasonably – construes this as an objective external reality that provides the basis for reliable communication with other warehouse personnel.

Figures 1, 2 and 3 below are screenshots from artefacts created to represent several aspects of state in the warehouse situation, as seen by a warehouse worker. (The scale of the models used for illustrative purposes is of course unrealistically small, but their character and use is sufficient to indicate the role that they can play in process modelling.)

Figure 1 depicts the physical state of the warehouse, showing the layout of the storage places and transportation platforms, and the location of items and information boards. Figure 2 depicts a form relating to the status of individual items in a redistribution process. Figure 3 depicts two of the many tables of information that together give the warehouse worker a more comprehensive view of the current status of items in the warehouse.

All these different aspects of state impinge on any particular worker, and play a part in shaping their legitimate role. The warehouse worker will be aware of all these aspects in decision-making: bearing in mind the physical locations and layout when dealing with an item (Figure 1), being able to assess the current status of a transaction through examining forms (Figure 2), and consulting inventories,

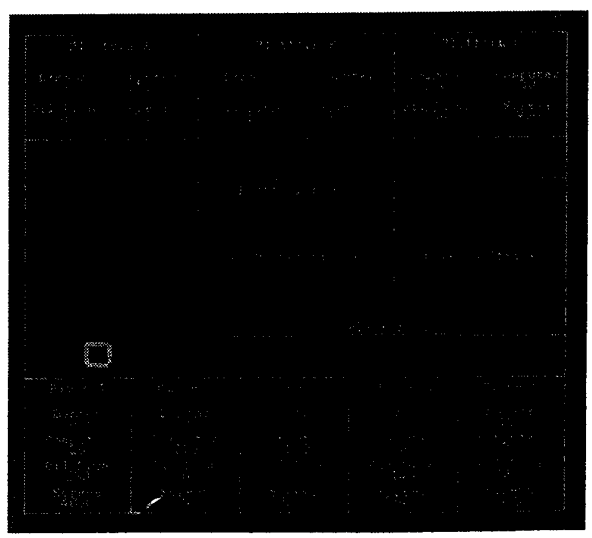


Figure 1. Physical State of Warehouse

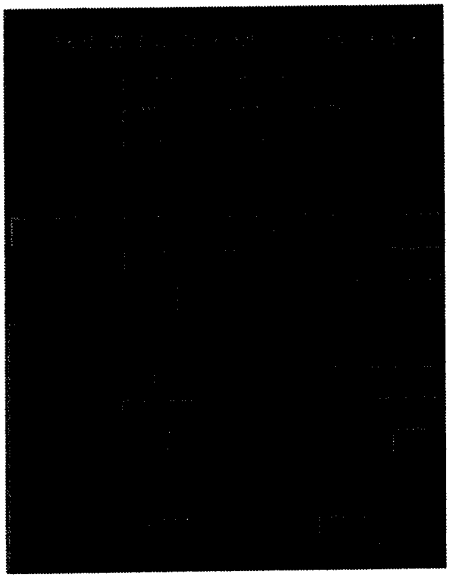
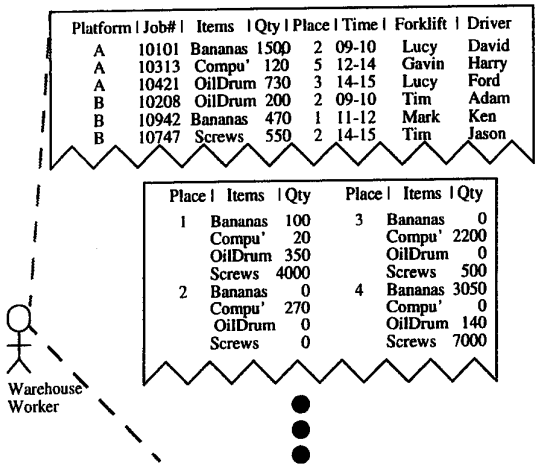


Figure 2. Form Showing Individual Item Status

work schedules and timetables when planning the movement of items.

There is much more to the state of the warehouse than these three aspects of state alone can express. In checking the status of items, there will typically be communication with other personnel. The architecture of the warehouse, and the locations of information boards and organisation of items have a significant impact on the abstract processing activity. The way in which the information on forms is embodied influences issues such as security: paper forms can be physically inaccessible, are hard to modify without detection and can be audited. There are many additional significant aspects of state that are not represented above, for instance, concerning the geographic location of lorries, drivers and other warehouses and factors such as traffic conditions. There is also hidden significance in the continuity associated with the presence and integrity of items and their environment, and a close connection between such ontological issues and the integrity of the processes themselves. For instance, it may be assumed that items are not prone to disappear or undergo transformations of state, that no substitution is made for an authentic item. What is more, participation in the process is in some sense an essential attribute of being an item, so that it may no longer be appropriate to regard a lost item as an item at all.



Platform	Job#	Items	Qty	Place	Time	Forklift	Driver
A	10101	Bananas	1500	2	09-10	Lucy	David
A	10313	Compu'	120	5	12-14	Gavin	Harry
A	10421	OilDrum	730	3	14-15	Lucy	Ford
B	10208	OilDrum	200	2	09-10	Tim	Adam
B	10942	Bananas	470	1	11-12	Mark	Ken
B	10747	Screws	550	2	14-15	Tim	Jason

Place	Items	Qty	Place	Items	Qty
1	Bananas	100	3	Bananas	0
	Compu'	20		Compu'	2200
	OilDrum	350		OilDrum	0
	Screws	4000		Screws	500
2	Bananas	0	4	Bananas	3050
	Compu'	270		Compu'	0
	OilDrum	0		OilDrum	140
	Screws	0		Screws	7000

Figure 3. Tables Showing Comprehensive Item Status

The significance of our approach to model-building is that there is flexibility to adapt state interactively and organically through cooperative activity in a distributed environment. This is achieved through our paradigm for state representation, which not only allows the state of the artefact to be changed by redefining variables, but is also sufficiently open as to allow reinterpretation of this state both through a shift in the perception of a single participant and through negotiation amongst participants. According to context, redefinition of variables can be interpreted as a state-transition, correction, or extension of the artefact. In distributed interactive use, the semantics of such artefacts is subtle enough to support exploration of all such elaborations of state as have been identified above.

3.2 Developing Warehouse Processes

Conventional process abstractions involve 'coordinatising' all possible situations with reference to the determinants of selected aspects of state. The aspects of a warehouse worker's perception of state represented in Figures 1, 2 and 3 reflect the traditional separation of decision support issues into organisational, tactical and strategic components, for instance. Such hierarchical organisation of state abstraction levels is intended to give conceptual control over processes and enable more effective management of agency. For instance, personnel are trained to correlate the physical condition and location of items with their status in processes. This allows managers to organise these processes without being themselves actively engaged in the lower level tasks such as identifying and marking items. Related abstractions are involved in using forms to testify in a persistent manner for real actions and observations that are ephemeral and without trace. The information hiding and encapsulation in object-oriented model-building paradigms are well-suited for such partitioning of state [3].

Useful as such abstractions are in representing processes that have been thoroughly validated through empirical study or long-established practice, trying to represent situated activity by abstract processes in this way can be problematic. As James describes so vividly in [4], the boundaries of state-as-experienced are ill-defined, and different perceptions of state are interrelated in highly complex, fluid and confusing ways. This makes it hard to circumscribe the state that impacts on any particular participant or activity. For instance, scheduling of activities for each worker has to be feasible, congenial and seen to be fair, and this is assessed in the context of personal circumstances and contingencies that arise through singular events. Business process activity is also viewed from many perspectives other than those of the participants themselves, such as those of the auditor ("what has been going on?" "Does it conform to regulations and standards?") and of the analyst ("what could be improved?" "how could processes be more efficient and stable?").

The development of useful processes from our models has two aspects: an observation-oriented analysis and an associated simulation of behaviour. The latter activity is still based around the participation of human agents in interaction with the constructed model, but represents a shift in emphasis from exploratory activity and model extension towards study of the intended process operation. Key issues in this prototype use are the identification of stable protocols for interaction and suitable stimulus-response patterns.

Observation-oriented analysis makes use of a special-purpose notation for describing agency. This is illustrated in the LSD account for the warehouse worker below. This account classifies the observables of an agent according to their status relative to the agent. A *handle* refers to an observable whose value can (perhaps conditionally) be changed by the agent, and an *oracle* to an observable that influences the agent in performing its actions. For example, a warehouse worker refers to the platform board and the forklift schedules when deciding which forklift and which platform to allocate to a redistribution task.

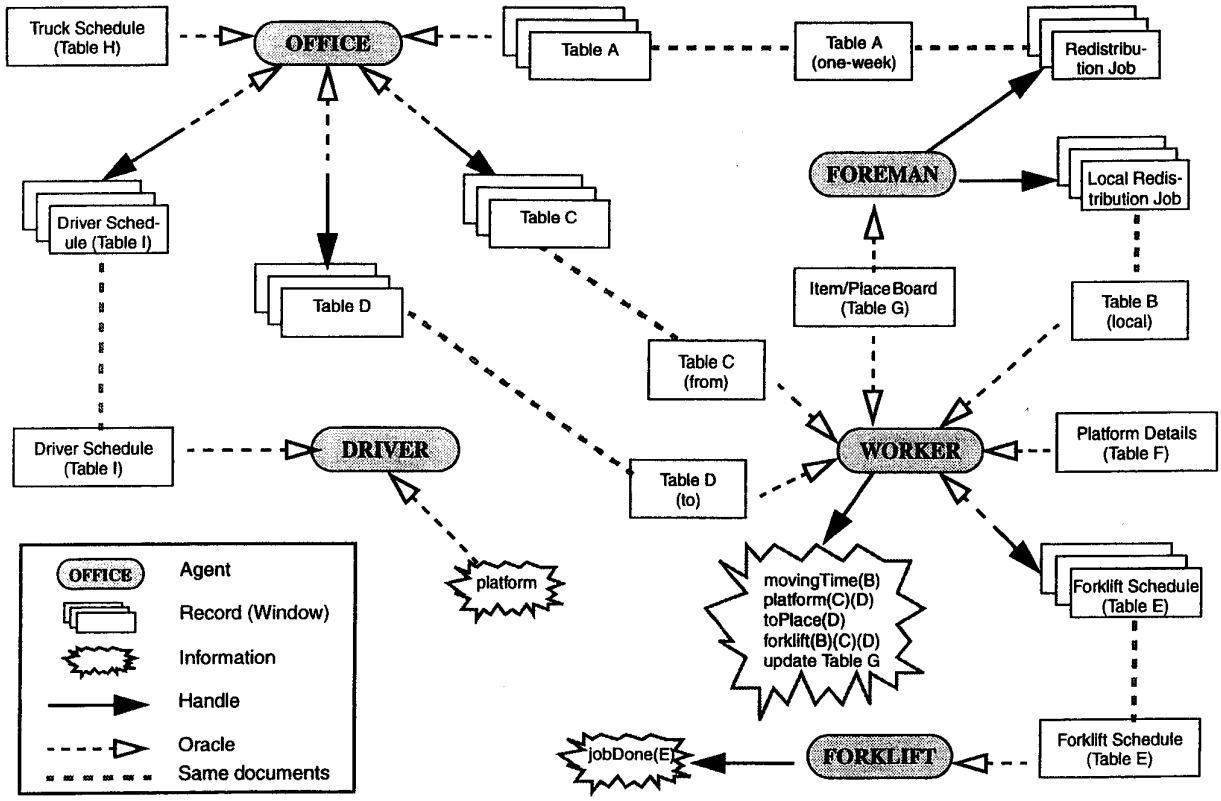


Figure 4. A Diagrammatic Summary of an LSD Account of Warehouse Processes

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agent warehouseworker {                                  // LSD Account //
oracle c_item, c_quantity, c_loadTime, d_item, d_quantity,
  d_unloadingTime, f_platform, f_time, f_forklift, e_time, e_item,
  e_quantity, e_from, e_to, e_jobDone, g_place, g_item, g_quantity
handle b_movingTime, b_forklift, c_platform, c_forklift,
  d_platfrom, d_forklift, d_toPlace, g_item, g_quantity
derivate
  table_E is rel_fn_of (table_B, table_C, table_D);
  table_F is rel_fn_of (table_C, table_D);
protocol
  for any forklift whose e_time is available for job in B
     ⇨ write b_movingTime, b_forklift;
  for any forklift and platform available for job in C and D
     ⇨ write c_platform, c_forklift, d_platform, d_forklift;
  if d_quantity(item) + g_quantity(place, item) ≤ MAX(place, item)
     ⇨ d_toPlace is g_place;
  if e_jobDone ⇨ update g_item, g_quantity;
}
```

Figure 4 is a diagrammatic summary derived from an LSD account of the interactions between all the agents engaged in the warehouse processes. The oracles to the warehouse worker are represented in the associated family of tables, where Tables F and G feature in Figure 3. The control that the warehouse worker exercises over handles is specified in the *protocol* of the LSD account. The dependencies between oracles in the warehouse worker's environment are conveniently represented by *derivates* in the LSD account, which express the way in which certain tables can be expressed in terms of others using relational algebra.

The interpretation of the LSD account is closely tied up with empirical investigation of the artefacts that are depicted in Figures 1, 2 and 3. In a manual warehouse system, the dependency between table contents represented in the LSD account might be maintained by direct copying of entries from one table to another, or by the use of carbon copying techniques. In a fully automated system, similar functionality could be delivered by using views in a relational database and incorporating triggering mechanisms to guarantee regular updates. The LSD account may be viewed as conceptualising the agent cues that enable processes to operate effectively and expressing their abstract perception of coherent state. Provided that this is consistent with the physical and perceptual facts, as attested by participative modelling of the appropriate artefacts, such an LSD account can be used as the basis for system redesign and implementation. Reference to how the oracles of one agent are linked to the handles of another in Figure 4 indicates how this account supplies a framework for defining the warehouse processes. Reference to the protocol, oracles and handles in the LSD account of an agent such as the warehouse worker indicates how the interfaces required to carry out the actions of its protocol should be defined.

4 Conclusions

Through a radical generalisation of spreadsheet principles, EM provides flexible and human-centred support for the design and construction of a wide range of interactive multi-user systems. The qualities of EM include:

- It offers computer-based support to the early, subjective provisional states of mind when a modeller is beginning to formulate and analyse a requirement for a piece of software, a design for a new business process, or any other 'system' which will eventually have automated computer support.
- It is experience-based and allows us to build a computer artefact in a truly experimental, open-ended fashion. We can in principle interact with the artefact in any way that makes sense when interacting with the referent.
- The role of experience in construction of an EM artefact makes for a new quality of interaction: one of close, continuous engagement – as in conversation.
- The quality of interaction, and the distributed nature of our models, allow for a new level of flexibility in exploring the appropriate balance between automated support and human intervention.

Acknowledgements

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