Modelling Multi-Facetted Purposes of Artefacts

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ABSTRACT

Whereas software variability deals with customisation and adaptability of software, we consider here the issue of modelling variability for Information System artefacts. We view variability in the larger perspective of the system meeting the purpose of many organisations and customer groups. We propose to represent this multi-facetted nature of a purpose through the notion of intentions and strategies organised as a map. The map is a directed, labelled, non-deterministic graph with intentions as nodes, and strategies to achieve intentions, as edges. Its nature allows the capture of different forms of variability through multi-edges between a pair of nodes thereby enabling many traversals of the graph from beginning to end. Besides, using the refinement mechanism of the map, it is possible to represent variability at different levels of detail. We show the power of a map to represent variability and, as an illustration, model the variations of the SAP Materials module as a map.

INTRODUCTION

Propelled by the failure of systems to meet user expectations, there has been a gathering trend to build ever more purposeful systems, those that achieve specific objectives of organisations. Goal modelling had its early beginnings in 1970s in the definition study of Hice and Turner [Hice74] and context analysis of [Ross77]. It was used in participative analysis in 1980s [Munford81] and was found in a few Object-oriented method-ologies of the 1990s [Rubin92] but really came into its own in Require-ments Engineering in the last decade. Goal modelling is used in RE [Dardenne93], [Anton98], [Kaindl00], [Rolland98], [Lamsweerde01], [Chung00] to elicit IS requirements that capture the strategic, high level, goals of an enterprise. By linking the rationale behind the system (the *why)* and the functional as well as non-functional requirements (the *what*) goal modelling is helpful in building more purposeful products.

In recent years, a new context in which IS products are developed has emerged. Whereas earlier, an IS product met the purpose of a single organisation and of a single set of customers, a product of today must be conceived in a larger perspective, to meet the purpose of several organisations and to be adaptable to different usage situations/customer sets. The former is typical of an ERP-like development situation whereas the latter is the concern of product-line development [Svahnberg01], [Bosh01] and adaptable software [Hui03]. In the soft-ware community, this leads to the notion of software variability which is defined as the ability of a software system to be changed, customised or configured to a specific context [Van Gurp00].

We believe that variability suggests a move from systems with a *mono-facetted purpose* to those with a *multi-facetted purpose*. Whereas the former concentrates on goal discovery, the multi-facetted nature of a purpose extends it to consider the many different ways of goal achieve-ment. For example, for the goal Purchase Material, earlier it would be enough to know that an organisation achieves this goal by forecasting material need. Purchase material is mono-facetted: it has exactly one strategy for its achievement. However, in the new context, it is

necessary to introduce other strategies as well, say the Reorder Point strategy for purchasing material. Purchase Material now is multi-facetted, it has many strategies for goal achievement. These two strategies, among others, are made available in the SAP Materials Management module.

In this paper, we suggest that to model the multi-facetted purpose of an IS product there is a need to balance goal-orientation with the introduc-tion of strategies for *goal achievement*. We use a formalism, the *Map* [Rolland99], for the representation of multi-facetted purposes. A *map* is a graph, with nodes as *intentions* and *strategies* as edges. An edge entering a node identifies a strategy that can be used for achieving the intention of the node. The map therefore, shows which intentions can be achieved by which strategies once a preceding intention has been achieved. Evidently, the map is capable of expressing goals and their achievement in a declarative manner.

In [Rolland99], we developed the *Map* as a means for representation of multi-models, a set of process models. A particular path from its START node to its END node was shown to be a process model. Our interest now is to view the *Map* in another way, as a means for capturing variability. This variability is not to be seen from the process perspective but from the product perspective: how do you specify the multi-facets of a product.

The rest of the paper is organised as follows. In section 2 we present how the MAP formalism allows us to represent variability and illustrate it in section 3 with variability in the SAP Material Management Module. Conclusions are drawn in section 4.

KEY CONCEPTS OF THE MAP

In this section we introduce the *key concepts* of a map and their relationships and bring out their relevance to model multi-facetted purposes.

A *map* provides a representation of a multi-facetted purpose based on a non-deterministic ordering of intentions and strategies. The key concepts of the map and their inter-relationships are shown in the map meta-model of Figure 1 which is drawn using UML notations.

- A *map* is composed of several sections. A section is an aggregation of two kinds of intentions, *source* and *target*, linked together by a *strategy*.
- An *intention* is a goal, 'an optative' statement [Jackson95] that expresses what is wanted i.e. a state that is expected to be reached or maintained. *Make Room Booking* is an intention to make a reservation for rooms in a hotel. The achievement of this intention leaves the system in the state, *Booking made.* Each map has two special intentions, *Start* and *Stop*, associated with the initial and final states respectively.
- A *strategy* is an approach, a manner, a means to achieve an intention. Let us assume that bookings can be made *on the Internet.* This is a means of achieving the *Make Room Booking* intention,

Figure 1. Map Meta-Model

Figure 3. Multi-Path of the map Make Confirmed Booking
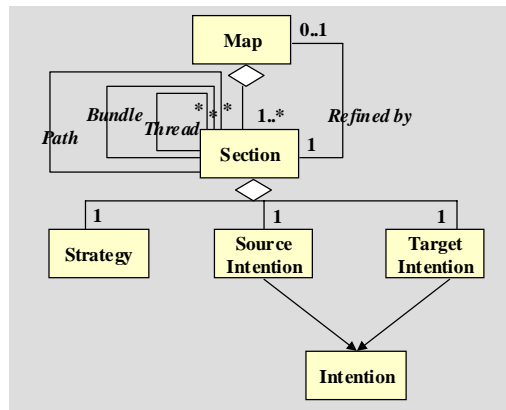
and is a strategy. *by visiting a travel agency* is another strategy to achieve the same intention.

- A *section* is an aggregation of the source intention, the target intention, and a strategy. As shown in Figure 1 it is a triplet $\langle I_{source}, I_{target}, S_{source\text{-}target}\rangle$. A section expresses the strategy $S_{source\text{-}target}$ using which, starting from I_{source}, I_{target} can be achieved. The triplet $\langle Start, Make\ Room\ Booking,\ on\ the\ Internet\rangle$ is a section; similarly $\langle Start, Make\ Room\ Booking,\ by\ visiting\ a\ travel\ agency\rangle$ constitutes another section.

A section is the basic construct of a map which itself can be seen as an assembly of sections. When a map is used to model a multi-facetted purpose, each of its sections represents a facet. The set of sections model the purpose in its totality and we will see below that the relationships between sections and between a section and a map lead to the representation of the multi-facetted perspective.

A map is drawn as a directed graph from *Start* to *Stop*. Intentions are represented as nodes of the graph and strategies as edges between these. The graph is directed because the strategy shows the flow from the source to the target intention (Figure 3).

- *Section relationships*: There are three relationships between sections (Fig.1) namely the *thread*, *path* and *bundle* which generate *multi-thread* and *multi-path* topologies in a map.
- *Thread relationship*: It is possible for a target intention to be achieved from a source intention in many different ways. Each of these ways is expressed as a section in the map. Such a map topology is called a *multi-thread* and the sections participating in the multi-thread are said to be in a *thread relationship* with one another. Assume that *Accept Payment* is another intention in our example and that it can be achieved in two different ways, *By electronic transfer* or *By credit card*. This leads to a thread relationship between the two sections shown in Figure 2.

It is clear that a thread relationship between two sections regarded as facets represents directly the variability associated to a multi-facetted purpose. Multi-faceting is captured in the different strategies to achieve the common target intention.

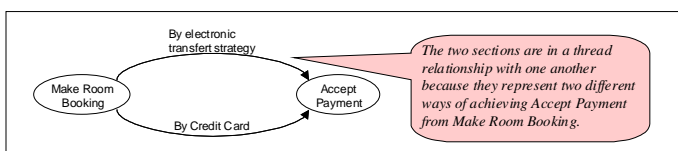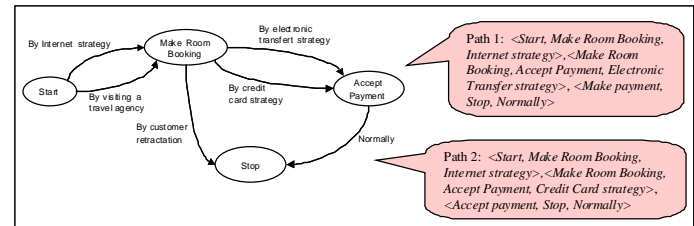*Figure 2. Example of Thread Relationship*

- *Path relationship*: This establishes a precedence/succedence relationship between sections. For a section to succeed another, its source intention must be the target intention of the preceding one. For example the two sections *<Start, Make Room Booking, On the Internet>*, *<Make Room Booking, Accept Payment, By credit card>* form a path.

From the point of view of modelling facets, the path introduces a composite facet whereas the section based facet is atomic.

Given the thread and the path relationships, an intention can be achieved by several combinations of sections. Such a topology is called a *multi-path*. In general, a map from its *Start* to its *Stop* intentions is a multi-path and may contain multi-threads. Let us assume in our example that it is possible to *Stop* either because a customer retracts from making the booking (*By customer retraction*) or after payment (*Normally*). Figure 3 shows the entire map with the purpose to *Make Confirmed Booking*. This map contains 6 paths from Start to Stop out of which two are highlighted in the Figure 3.

Clearly, the multi-path topology is yet another way of representing the multi-facetted perspective. Multi-faceting in this case is obtained by combining various sections together to achieve a given intention of the map. Consider for instance the intention Accept payment in Figure 4; there are four paths from Start to achieve it; each of them is a different way to get the intention achieved and in this sense, participates to the multi-faceting. Each path is a composite facet composed of two atomic facets. This can be extended to the full map which can be seen as composed of a number of paths from Start to Stop. This time these paths introduce multi-faceting but to achieve the intention of the map which in our example, is Make Confirmed Booking.

- *Bundle relationship*: Several sections having the same pair $\langle I_{source}, I_{target}\rangle$ which are mutually exclusive are in a *bundle relationship*. The group of these sections constitutes a *bundle*. Notice that the difference between a thread and bundle relationship is the exclusive OR of sections in the latter versus an OR in the former.
- *Refinement relationship*: Figure 1 also shows that a section of a map can be refined as another map through the *refinement relationship*. The entire refined map then represents the section as shown in Figure 5. Refinement is an abstraction mechanism by which a complex assembly of sections at level *i+1* is viewed as a unique section at level *i*. As a result of refinement, a section at level *i* is represented by multiple paths & multiple threads at level *i+1*.

From the point of view of multi-faceting, refinement allows to look to the multi-facetted nature of a facet. It introduces levels in the representation of the multi-facetted purpose which is thus, completely modelled through a hierarchy of maps.

To sum up:

- The purpose of the artefact is captured in a *hierarchy of maps*. The intention associated to the root map is the high level statement about the purpose. Using the refinement mechanism each section of the root map can be refined as a map and the recursive application of this mechanism results in a map hierarchy. At successive levels of the hierarchy the purpose stated initially as the intention of the root map is further refined.

• At any given level of the hierarchy, the multi-facetted dimension is based on *multi-thread* and *multi-path* topologies. Multi-thread introduces local faceting in the sense that it allows to represent the different ways for achieving an intention directly. Multi-path introduces global faceting by representing different combinations of intentions and strategies to achieve a given map intention. Any path from Start to Stop represents one way of achieving the map intention, therefore the purpose represented in this map.

SAP R/3 MATERIALS MANAGEMENT MAP
In this section we show the use of the Map to capture the multi-facetted purpose of a product and take the SAP R/3 Materials Management (MM) module to illustrate this.

This module provides automated support for the day-to-day operations of any type of business that entails the consumption of materials. It consists of five key components starting from materials planning (MM-MRP Materials Requirements Planning), through purchasing (MM-PUR Purchasing), managing inventory (MM-IM Inventory Management), managing warehousing (MM-WM Warehouse Management), to invoice verification (MM-IV Invoice Verification). It also includes two support components, MM-IS Information System and MM-EDI Electronic Data Interchange.

In its totality, the MM module can be seen to meet the purpose, *Satisfy Material Need Efficiently*. This is the intention of the root map shown in Figure 4. The map shows that to meet this purpose two intentions have to be achieved, namely *Purchase Materia*l and *Monitor Stock*. These reflect the conventional view of materials management as "procuring raw material and ensuring effectiveness of the logistics pipeline through which materials flow" [Garg99]. Evidently, there is an ordering between these two intentions: stock cannot be monitored unless it has been procured. This is shown in the Figure by the section <*Purchase Material, Monitor Stock, Out-In strategy* >.

The map of Fig. 4 shows 25 paths from *Start* to *Stop*, 5 following the *Bill for expenses strategy*, 10 following the *Planning Strategy*, and 10 following the *Manual strategy*. Thus, the map is able to present a global perspective of the diverse ways of achievement of the main purpose. When a more detailed view is needed, then it becomes necessary to focus more specifically on the multi-facetted nature of each intention found in the 'global' map. The detailed view of the intentions contained in Fig. 6 is brought out in turn below.

### The Multiple Facets of Purchase Material
The multi-facetted nature of *Purchase Material* is shown in Fig. 4 by including three strategies for its achievement (a) *Planning strategy*, (b) *Manual strategy* and (c) *Reminder strategy*. The three facets are <*Start, Purchase Material, Planning strategy*>, <*Start, Purchase Material, Manual strategy*> and <*Purchase Material, Purchase Material, Reminder strategy*>.

Subsumed in the first facet are two mutually exclusive facets, one that allows purchase to be made when stock falls to the reorder point and the other for purchasing as per the planned material need. As discussed in section 2, these two are captured in a bundle consisting of the *Reorder point strategy* and *Forecast based strategy*. The second facet, <*Start, Purchase Material, Manual strategy*>, allows the buyer to manually enter a purchase requisition leading to the generation of the purchase order. The third facet is used to remind the vendor to deliver material when the delivery is not made in due time.The bundled strategies correspond to the SAP functions of MM-MRP Forecast Based Planning and Reorder Point Planning respectively whereas the manual strategy is part of the MM-PUR component. It can be seen that the component structure of SAP does not directly reflect the alternative functionality of achieving the same goal.

Multiple Facets of Monitor Stock
Monitor Stock is the second key intention of the material management map. The intention represents the management goal of ensuring proper

Figure 4. Material Management Map
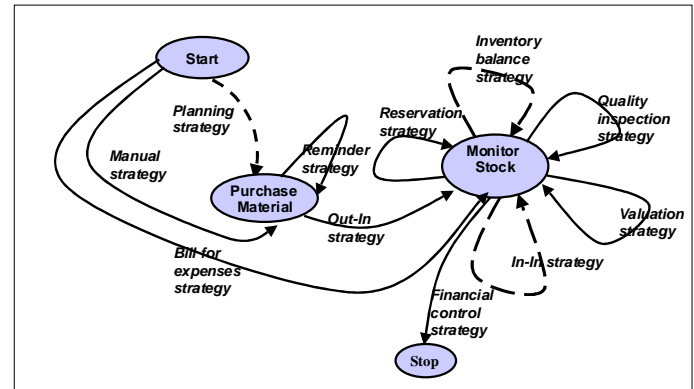
posting of procured material and effectiveness of material logistics while maintaining financial propriety. This suggests that *Monitor Stock* has three classes of facets (a) the procurement/posting class, (b) the logistics class, and (c) the financial class. The facets in each class are as follows:

Procurement/Posting Facets
Procurement of material can be done either against a purchase order or without a formal purchase order, directly from the market. In the latter case, material is immediately ready for posting whereas in the former case, posting is done after delivery is made against the purchase order. Thus, we have two facets of this class: (i) Posting of material delivery against a purchase order (ii) Posting of material procured through direct purchase.

These correspond in the map to the *Out-in strategy* and *Bill for expenses strategy*, respectively. In SAP, the facet represented by the section <*Purchase Material, Monitor Stock, Out-In strategy*> is covered by functions of the MM-IM and MM-WM components whereas <*Start, Monitor Stock, Bill for expenses strategy*> is a function of MM-IV, the Invoice Verification component.

The facet <*Purchase Material, Monitor Stock, Out-In strategy*> is, in fact, a compound one. It represents the variety of ways in which compliance of delivered material with the purchase order can be ensured and material posting made. Therefore, its refinement (Fig.5) reveals a complex assembly of facets that can be represented through a map at a lower level.

Since <*Purchase Material, Monitor Stock, Out-In strategy*> does not permit stock posting unless material delivery complies with the purchase order, its refinement contains an ordering of the two intentions, *Accept Delivery* and *Enter Goods in Stock*. The former has four facets, one for the case where delivery is strictly according to the purchase order and three facets that allow delivery to be accepted within specified tolerances from that in the purchase order. The four facets are as follows:

• The delivery complies with the purchase order
• Reconciliation against the purchase order has to be done
• Reconciliation between the differing units used by the supplier and the receiver has to be done
• Reconciliation of under/over delivery has to be done

These correspond in Fig. 5 to the four multi-threads identified by the strategies *Okay strategy, Reconciliation by PO recovery*, *Reconciliation of unit difference*, and *Reconciliation of under/over delivery*. The nature of the three *Reconciliation* facets is such that one or more can be simultaneously used. Therefore, these strategies do not form a bundle but are each represented as a thread.

Now consider the intention *Enter Goods in Stock*. This displays two facets for entering goods in stock (a) when delivery is made directly to the consumption location and (b) when delivered goods are stored in a

Figure 5. Refinement of <Purchase Material, Monitor Stock, Out-In strategy>
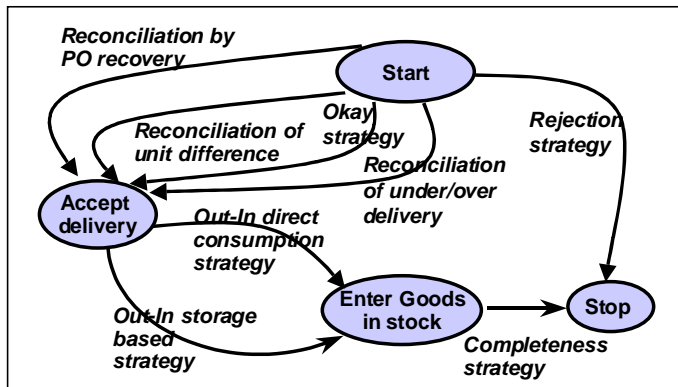
warehouse. As shown in Fig. 5, these two ways of achieving *Enter Goods in Stock* correspond to the two strategies, *Out-In direct consumption* and *Out-In storage based strategy*.

The target intention, *Monitor Stock*, of the facet under refinement is achieved in the map of Fig. 5 when the intention *Stop* is achieved. Evidently, this happens when either the material delivered is rejected and no stock entry is made or when, after entering the accepted delivery in stock, all subsequent housekeeping is done to take into account the consequences of entering goods in stock. These two facets of *Stop* are represented in Fig. 5 by *Rejection strategy* and *Completeness strategy* respectively.

Material Logistics Facets

Facets in this class enter the picture only after initial posting of stock has been made by the class of procurement/posting facets of *Monitor Stock*. The interesting question now is about the movement of stock and how this movement is kept track of. That is, *Monitor Stock* has to be repeatedly achieved after each movement to/from warehouses, to consumption points or for quality inspection. This gives us the three facets:

- Control of material movement to/from warehouses
- On-time transfer of material to consumption points
- Quality control of the material transferred

These correspond in the map of Fig. 6 to the *In-In*, *Reservation*, and *Quality inspection strategies*. These strategies have *Monitor Stock* as both their initial as well as their target intentions. This represents the repeated achievement of *Monitor Stock*.

Of the three foregoing facets, the first, represented by the section <*Monitor Stock, Monitor Stock, In-In strategy*> needs further explanation. In fact, subsumed in this facet are two mutually exclusive facets of *Monitor Stock*. These correspond to the cases when the stock to be moved spends a long time in transit or when immediate transfer is possible. As before, the section <*Monitor Stock, Monitor Stock, In-In strategy*> is represented as a bundle of two sections in Fig. 6b having strategies *One-step transfer* and *Two-step transfer*. The former corresponds to immediate transfer and the latter to delayed transfer. In SAP, this bundled section is covered partly by MM-IM and MM-WM and has a relationship with Financial Accounting, Assets Management, and Controlling.

Financial Propriety Facets

The third class of facets of *Monitor Stock* deals with financial propriety. Not only must it be ensured that stock on hand is physically verified but also it should be financially valued. Thus we have two facets in this class

- Physical stock taking of the material
- Valuing the stock for balance sheets

These are represented in Fig. 4 by the *Inventory balance* and *Valuation* strategies respectively. As for the material logistics class of facets, these are also concerned with the repeated achievement of *Monitor Stock*. Therefore, both the source and target intentions of these strategies is *Monitor Stock*.

The facet corresponding to the <*Monitor Stock, Monitor Stock, Inventory balance strategy*> section subsumes three different ways of physical stock taking which are modelled as a bundle of the three *periodic*, *continuous* and *sampling* strategies. This bundle is handled by the MM-IM component in SAP.

The facet represented in Fig. 4 by the section <*Monitor Stock, Monitor Stock, Valuation strategy*> can itself be treated as a bundle of mutually exclusive facets represented by strategies such as LIFO and FIFO. In SAP, only LIFO valuation is available as a function in MM-IM.

Completing Satisfy Material Need Effectively

The complete fulfilment of *Satisfy Material Need Effectively* requires that the financial aspects of material procurement are properly handled. Thus completion, corresponding to the achievement of *Stop* of Fig. 6 is done by the *Financial control strategy* allowing the flow from *Monitor Stock* to *Stop*. In SAP, this takes the form of the Invoice Verification component, MM-IV.

When a multi-facetted product like the SAP MM is to be adopted, then the task of the adoption process is to select the facets of the MM map that are of relevance.

CONCLUSION

Requirements Engineering has principally looked at the needs of systems of a single organisation. The discovery of the goals of a system is the key whereas the aspect of how these goals are to be achieved is de-emphasised. In the new world of mergers/acquisitions and, in general, of inter-organisation co-operation the mere discovery of goals is not enough. Systems having the same goals are unable to mesh smoothly because of different strategies of goal achievement adopted in different organizations. Thus, RE needs to place somewhat greater emphasis on goal achievement than it has traditionally done. Our proposals here constitute an approach in this direction: a map expression provides a synthetic view of the variability of an artefact in a relatively easy to understand way. It represents system goals and their achievement in one integrated fashion and in an unbiased way.

We are now moving to developing an agent based implementation that allows the dynamic selection of the variations depending on the situation of the user of the software. We expect this selection to be driven by the variable needs as expressed in the map and then get translated to the desired system functionality.

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