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Systems Design for Requirements Expressed as a Map

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ABSTRACT

We develop a whole life cycle method, from requirements engineering to system construction, starting from the notion of a Map. A Map represents requirements in terms of intentions and strategies to achieve intentions. We propose to transform these requirements into a Data Flow Diagram. We show that a Map and a DFD are compatible for this transformation and develop transformation rules. The materials management example is used to illustrate the approach.

0. INTRODUCTION

A number of approaches for requirements engineering exist: goal-oriented [Ant98], [Dar93], [Lam01], scenario-oriented, goal-scenario/ coupling-oriented [Kai00], [Rol98], and the intention/strategy approach of a Map [Rol99]. Similarly, a number of approaches for system design are available [Oll91], process-oriented, data-oriented, behaviour-oriented, and Object-oriented. With the emergence of requirements engineering, it is necessary now to develop methods for conversion of requirements to system design. The contribution of this paper is in the development of such an approach. We address this proble by coupling the Map [Rol99] for requirements with DFD for systems design. We show that these are good candidates for this coupling and the describe the mapping between them.

The basic notions of a map are:

1. An *intention:* a goal, 'an optative' statement [Jackson95] that expresses what is wanted i.e. a state that is expected to be reached. There are two special intention, *Start* and *Stop*.
2. A *strategy* is an approach to achieve an intention.
3. A *section* is a triplet $<I_{source}, I_{target,} S_{source-target}>$. It expresses the strategy $S_{source-target}$ using which, starting from I_{source}, I_{target} can be achieved.
4. There can be many strategies linking the same $< I_{source}, I_{target>}$ pair. These can be used in a mutually exclusive way or simultaneously.
5. An ordering can be defined between sections.
6. A section can be refined as another map.

A map is a directed graph from *Start* to *Stop* with Intentions as nodes and Strategies as edges. System requirements are captured in a *hierarchy of maps*.

1. THE MAP-DFD COUPLING

The divergence between the aims and objectives of the map and a DFD is shown in Table I. Perhaps, only the third row of the Table requires explanation. It shows the position of the DFD and the map in the system life cycle. DFD designers interact between requirements engineers and system constructors whereas map designers interface between organizational stakeholders and system designers.

Table II compares the semantics behind the notations of the Map and the DFD. All rows except the fifth are self explanantory. The fifth row says that alternative flows are missing in a DFD: in a map an intention can be achieved in different ways but in the DFD a process operates on specific data.

Table I. Comparison of aims and objectives

	Data Flow Diagram	Map
Abstraction level	System **design** specification: a sequence of *processing steps and associated data.*	System **requirements** specification: a *sequence of intentions and associated strategies*
Purpose	*arrive at the modular structure* of the program	*decide the process model that* meets the intention of the system
Interface	With the system construction team and requirements engineering team	With organizational stakeholders and system designers
Usage	Translate to a construction design	Select a process model that bets fits organizational needs and use it for system design

Table II: Comparison of the two notations

Representation	Data Flow Diagram	Map
Circle	Process	Intention
Flow in	Data input to the target process	Strategy for achieving target intention
Flow out	Data produced from the source process	Strategy enabled by achievement of source intention
Store	Yes	No
Alternatives	No alternative data flows into a process	Yes. Property 4 of Map
Ordering	Sequential data flow	Sequence of sections
Hierarchy	DFD hierarchy	Map hierarchy

2. CONVERTING TO A DFD

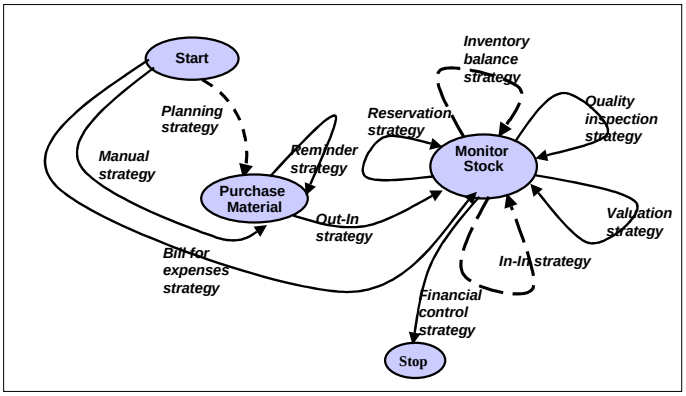
We postulate Map-DFD mappings as follows:

1. An intention is an 'optative' statement and cannot be mapped to a process or a data flow.
2. A strategy is a course of action and can be executed. The only executable component in the DFD is a process. Every process must correspond to a strategy.
3. The execution of a strategy achieves the state of an intention. Output data can be inferred from it. Thus, state maps to an outward data flow.
4. The inward data flow into a strategy (represented as a process) is the outward data flow obtained from (3).
5. Since sections of a thread have the same source and target states, such sections can all be mapped to a single process in a DFD.
6. Since only a single section is chosen from a bundle, the mapping of bundles sections follows rule (2) above.
7. Data stores are to be discovered when a detailed reasoning on the DFD produced is done subsequently.
8. Hierarchies of maps can be naturally converted into DFD hierarchies by the application of rules 1-6 above.

3. A MATERIALS MANAGEMENT MAP

We take the materials management domain as our example. We present the salient features of a Map for the SAP R/3 Materials Management

Figure 2. The material management map



(MM) module. A detailed presentation together with the reasoning behind the map can be found in [IRMA2005].

In its totality, the MM module can be seen to meet the intention, *Satisfy Material Need Efficiently*. This is the intention of the root map shown in Figure 2. To meet this purpose two intentions have to be achieved, *Purchase Materi*al and *Monitor Stock* in that order. This is shown by the section *<Purchase Material, Monitor Stock, Out-In strategy >*.

The three sections for *Purchase Material* (Fig. 2) are *<Start, Purchase Material, Planning strategy>, <Start, Purchase Material, Manual strategy> and <Purchase Material, Purchase Material, Reminder strategy>*. Subsumed in the first section are two mutually exclusive sections, (a) for purchase when stock falls to reorder point and (b) for purchasing as per planned material need. The second section, *<Start, Purchase Material, Manual strategy>*, allows the buyer to manually enter a purchase requisition leading to the generation of the purchase order. The third section is used to remind the vendor to deliver material when delivery is not made in due time.

Monitor Stock has three classes of sections (a) procurement/posting, (b) logistics, and (c) financial as follows:

(a) Procurement/posting sections

Procurement/posting of material can be done either against a purchase order, or directly from the market. Thus, we have two sections in the map, *<Purchase Material, Monitor Stock, Out-In strategy* and *<Start, Monitor Stock, Bill for expenses strategy>* respectively.

The section *<Purchase Material, Monitor Stock, Out-In strategy>* is refined (Fig.3) into a lower level. Its refinement contains an ordering of the two intentions, *Accept Delivery* and *Enter Goods in Stock*. The former has four sections, as follows:

- Delivery complies with the purchase order, *Okay strategy*
- Reconciliation against the purchase order has to be done, *Reconciliation by PO recovery*

Figure 3. Refinement of <Purchase Material, Monitor Stock, Out-In strategy>

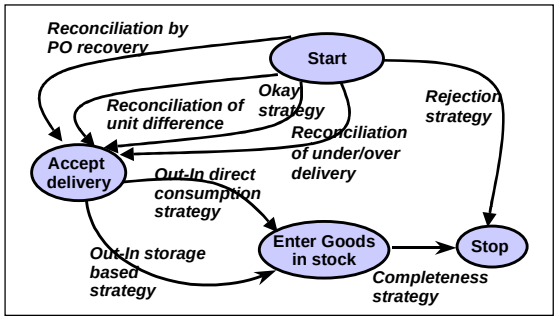


Table III. The states of the intentions

Intention	State
Purchase Material	Needed Quantity of Material Ordered
Monitor Stock	Material in Stock
Satisfy Material Need	Material made available
Accept Delivery	Material Quantity received
Enter Goods in Stock	Stock up-to-date

- Reconciliation between the differing units used by the supplier and the receiver has to be done, *Reconciliation of unit difference*
- Reconciliation of under/over delivery has to be done, *Reconciliation of under/over delivery*

Now, *Enter Goods in Stock* displays two sections (a) when delivery is made directly to the consumption location by *Out-In direct consumption strategy* and (b) when delivered goods are stored in a warehouse, the *Out-In storage based strategy*.

The target intention, *Monitor Stock*, of the section under refinement is achieved upon reaching *Stop*. This happens when delivery is rejected or when, after accepting delivery, appropriate housekeeping is done.

(b) Material logistics sections
These correspond in Fig. 2 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*.

(c) Financial propriety sections
Not only must it be ensured that stock on hand is physically verified but also it should be financially valued. Thus we have two sections
- Physical stock taking
- Valuing

These are represented in Fig. 2 by the *Inventory balance* and *Valuation* strategies respectively. 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*.

Table III shows the intentions of the maps and the states reached upon the fulfillment of these.

4. THE DFD OF MATERIALS MANAGAMENT

As discussed above, first we have to make a selection from the map. Let it be that from the map of Figure 2, the *Bill for Expenses strategy* and the *In-In strategy* are not selected. Additionally, from the bundle,

Planning strategy, only the *Forecast based strategy* is found to be of interest. Then according to the conversion rules, for the material management map we get the DFD shown in Figure 4.

The mapping of strategies to processes is shown in Table IV. Reference to Table III shows that that states of the intentions directly lead to the

Figure 4. The material management DFD

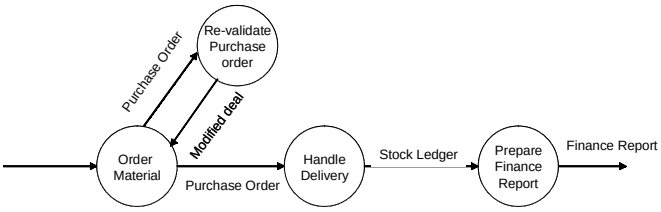


Table IV. Mapping of the material management map

Strategy	Process
Planning strategy Manual strategy	Order Material
Out-In strategy	Handle delivery
Reservation strategy Quality inspection strategy Valuation strategy Inventory balance strategy	Handle Delivery
Financial control strategy	Prepare Finance Report
Reminder strategy	Re-validate Purchase order

Figure 5. The DFD of the refined map

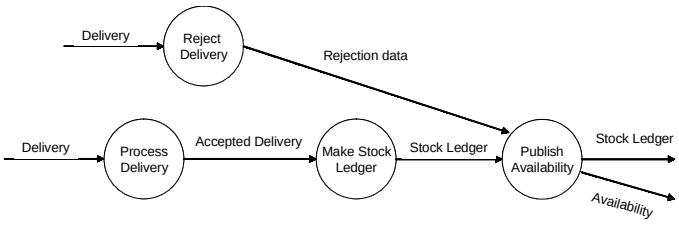


Table V. Mapping of the refined map

Strategy	Process
Reconciliation by PO recovery Reconciliation of Unit difference Okay strategy Reconciliation of under/over delivery	Process delivery
Out-In storage based strategy	Make Stock Ledger
Rejection strategy	Reject Delivery
Completeness strategy	Prepare Finance Report

data on the data flows of Figure 4. Perhaps, the only mapping needing some explanation is the Reminder strategy. Its purpose is to remind the supplier in the event of non-delivery and consequent non-compliance with the purchase order. Since there is non-compliance, the purchase order is to be modified to reflect the new negotiated agreement. This is done by mapping the Reminder strategy to Re-validate Purchase Order.

Now, consider the map of Figure 3. Let all the sections between Start and Accept delivery be selected. However, only the Out-In storage based strategy is chosen since all material is placed in the warehouse before issue. Let the Rejection and Completeness strategies, both be chosen. The DFD is shown in Figure 5.

The mapping of strategies to processes are straight-forward and is shown in Table V. Again, the DFD shows data flows whose data can be directly surmised from the states of the intentions of the map of Figure 3.

5. CONCLUSION

Since a map and a DFD are both process oriented, they form a natural pair. The proposed transformation rules are syntactic in nature and highly amenable to automation. For full life cycle coverage, the traditional DFD to construction design techniques are to be used.

In the future, we shall deal with reverse engineering, going from a DFD to a Map.

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