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A navigation metaphor to support mobile workflow systems

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Abstract. Mobile devices have enabled the development of a new breed of enterprise solutions. Oracle, SAP, IBM, and others are offering mobile clients (e.g. ERP, BI, CRM) for iPhone and Android devices. Nonetheless, in the field of workflow management systems (WfMS) the progresses do not support well mobile workers. In this paper we explore how metaphors can be used to drive the development of mobile workflow systems. Our approach relies on the use of the TomTom metaphor to establish an *isomorphism* between car navigation systems and WfMS. Based on the isomorphism, we used the Technology Acceptance Model (TAM) to provide a first validation of the approach. The positive results led us to implement an early prototype to be used as a proof of concept and to identify important requirements such as context information.

Key words: Metaphors, workflow management, navigation systems, mobile workers, process models.

1 Introduction

The last decade has seen substantial progresses in the development of workflow management systems (WfMS). Nonetheless, mobility was overlooked. Systems were mainly confined to organizational 'firewalls'. IBM WebSphere MQ Workflow, Oracle BPM Suite, SAP NetWeaver BPM, etc. are all major enterprise systems which function in hermetic organizational ecosystems (see [1]).

To address this gap in the field of mobility, our approach consisted on finding a metaphor to derive new paradigms for WfMS to support mobility. The importance of metaphors in systems development has long been identified as a catalyst for the success of information systems [9]. In our work, we argue that the use of a TomTom-like interface will encourage users to transfer knowledge about this familiar system of everyday experience to the operation of mobile workflow management systems to ease understanding of its structure and functionality [8]. More precisely, we explore the familiar features of car navigation systems as a catalyst to foster process navigation by establishing an analogy between networks of roads and the graph structure of a process. For instance, we map the well-known situation of driving into a dead-end road with the existence of a logical deadlock in a process instance. The need for more TomTom-like functionalities for WfMS to make systems more user-friendly was first identified in [12]. Many mappings between TomTom and workflow management systems may be derived, e.g., by creating interpretations of traffic symbols in the context of workflow management - some of which will be shown in Section 2.1. It became clear that it was a benefit to think about metaphors rather than to simply follow the more traditional approach and create formal requirements specifications [15].

To better convey our goal, Figure 1 shows a mockup of a car navigation system which was adapted to include several information elements related to process models and instances (labeled with 1-5) rather than to travels and trips. It is for this type of navigation applications that we concentrate our attention on. We contend that symbolism holds the promise to develop a new wave of workflow systems (c.f. [8]). In this particular example, the name of the highway, on the top of the figure and marked with (1), was replaced by the name of the currently executing process and its process identifier (i.e. `'Request Quote'` and `'P3'`); the number of remaining kilometers to reach the destination has been replaced by a process Key Performance Indicator (KPI) (see label (2)); label (3) indicates at what time the instance is expected to be completed; the speedometer was replaced by the current cost of the process (see label (4)); and label (5) marks a road selection in a highway which indicates a path selection (i.e. an XOR-split) in the process model. Naturally, the design of a high-fidelity prototype for the mockup of Figure 1 would not include all graphical elements. For example, the skyline may not find a correspondence in mobile workflow applications.

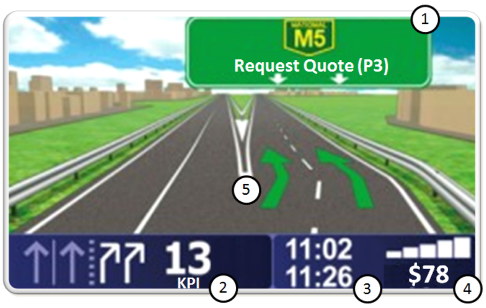

Fig. 1. The use of the car navigation metaphor to inspire process model navigation

This paper is structured as follows. Section 2 describes an isomorphism between the elements present in car navigation systems and workflow systems.

Section 3 describes the use of the Technology Acceptance Model [4] to provide a first validation of our approach. Section 4 describes the implementation of a running prototype which provides a proof of concept for the metaphor. Section 5 provides the related work in this field. Finally, Section 6 presents our conclusions.

2 Process model navigation

Most traditional process models are based on a graph-based representation for specifying how a business process or workflow operates. Let us use Petri nets to model processes. The question to be asked is *"how can we establish an analogy between a Petri net and a geographic map in the context of a car navigation metaphor?"*. We established the following fundamental mappings:

– Process models correspond to geographic maps
– Process instances correspond to moving vehicles
– Process places correspond to route sections and intersections
– Process transitions correspond to routes

In other words, a process model (i.e. a graph) which links places with transitions, defining a more or less ordered pattern, is describable in terms of a network of streets, roads and highways. Two streets are linked, if the transitions they represent lead to the same place. Since processes are essentially planar structures, the corresponding route network has a two-dimensional structure. We use the term *route* as an abstraction concept to refer to a street, highway, road, etc.

By analyzing the features that can be implemented for process navigation using a car navigation metaphor, we created a taxonomy of three important concepts to be considered: topology, connectivity, and landmarks.

2.1 Topology

The topology, or structure, of a process contains specific elements (such as splits and joins) which can find a mapping counterpart in a car navigation metaphor. Let us use the workflow patterns identified in [13] as a starting point and analyze how they can be matched to a split road, a road junction, a traffic light, a dead end, a roundabout and the notion of distance.

– *Split road.* An exclusive choice (XOR-split) and a multi-choice (OR-split) can be represented with a split road, i.e. a point where a flow of traffic splits. See Figure 2.a) for a possible road sign to use to represent a process split. A parallel split (AND-split) can be represented with various parallel lanes running in the same direction (see Figure 1, label (5)).
– *Road junction.* The process synchronization pattern (AND-join) and the simple merge (XOR-join) can all be represented with a road junction, i.e. a place where two or more roads meet.

– *Traffic light.* The structured synchronizing merge (OR-join sync) can be effectively illustrated with a traffic light. When an instance stops at a traffic light, users can immediately understand that a synchronization point has been reached (see Figure 2.b).
– *Dead end.* A process with a deadlock, i.e. a situation where an instance cannot continue to be executed anymore, can be made graphically visible in a navigation system using the road dead end sign (see Figure 2.c).
– *Roundabout.* Many cyclic process models include small repetitive cycles for error checking or quality improvements. These small cycles composed of a few transitions can be made explicit and be represented using a roundabout sign (see Figure 2.d).
– *Distance.* Route networks are spatially extended webs. It is possible to work with two types of distance measures: topological and geometrical. Topological route length is computed from the number of nodes (i.e. transitions or places) of a path; while the geometrical length is the sum of the lengths of all transitions of a path.

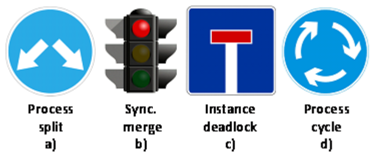

Fig. 2. Using road signs to express process and instance structures and behaviors.

2.2 Connectivity

Connectivity explores process transitions (i.e. tasks) that connect places. In geographical maps, connectivity is expressed using streets, avenues, highways, walking paths, etc. Routes can be used to portray the static nature of process models and the dynamic behavior of process instances. For example,

– *Route type.* The frequency a transition is executed in the context of a process instance or in the context of several instances can be represented using different types of routes. For example, a transition which is rarely executed can be represented using a dirty road; a transition with an average number of invocations can be represented with a lane; and a highway can be used to indicate frequently executed transitions.
– *Route failure.* Often a process transition can stop functioning due to an underlying problem in the information system that supports it (e.g. database failure, incorrect login/password, Web service invocation error, etc.). In such a case, the failure can be illustrated in real-time as a route being interrupted by landslides.

- *Multiple lanes.* The workflow parallel split pattern (i.e. an AND-split) introduces the concurrent execution of two of more instances which were split at some point. This concurrent execution can be visualized using additional routes which are parallel to the one followed by an instance.
- *Route names.* Since routes represent transitions, a route inherits its name from the transition it represents (see Figure 1, label (1)). This is static information associated with a process model, rather than with dynamic instances.
- *Route duration/cost.* For the duration of routes (i.e. transitions), the research done in the context of Workflow QoS (Quality of Service) [2] can be applied to enable each route to have a duration model. Quantitatively, the elapsed time or remaining duration of a route can be mapped to a concept similar to the one of physical distance in kilometers.

In these five examples, transitions and routes represent the static nature of design time processes. While routes characteristics represent the dynamic nature of processes instances.

2.3 Landmark

In a map some aspects are more relevant than others. For example, Points Of Interests (POI) indicate places which are worth visiting. The notion of landmark brings the notion of frequency, clustering, and containment for process navigation.

- *Frequency.* To express the importance of a place, which is often visited by process instances, a POI can be used. For example, an airport can illustrate a busy place where many instances flow.
- *Clustering.* Navigation maps identify areas which aggregate similar elements. For example, a city clusters similar roads (usually streets). In the same way, the elements of a process can also be clustered based, for example, on the similarity of transitions. The size of clusters can then be represented differently to express their relevance.
- *Containment.* Processes are often built by relying on subprocesses which define containment relationships. The notion of a process which contains subprocesses, which in turn contains yet another subprocess, can be expressed by using a linear hierarchy of city → town → village or alternatively, country → state → county. As instances 'travel' from a process to a subprocess, the navigation system can change the visualization context.

Implementing frequency, clustering, and containment using a semantic layer of information can provide environments characterized by intuitive clues (e.g. POI, cities, and towns) to the static and dynamic structure of processes.

2.4 Limitations

On the one hand, the use of metaphors has the advantage of enabling users to reapply the knowledge they already have from a domain. On the other hand, a metaphor might involve the danger that it does not go far enough and that certain characteristics cannot be well supported. For example, while Section 2.1 suggests multiple lanes to be interpreted as a parallel split, the analogy maybe hard to understand and implement. Since there are multiple lanes, one needs to be selected. It is not possible to drive on multiple lines in parallel. One solution can be to duplicate the "car" in different lanes simultaneously. Naturally, this scenario does not typically happens in real life. In a parallel split, the need to represent activities executing asynchronously is also a requirement.

To reduce complexity, navigation can be combined with process view mechanisms to enable, e.g., zooming in/out by aggregating/removing parts of the process. Similarly, views can be used to provide personalized versions of a process omitting activities not relevant to the current "driver" (see Section 2.3).

3 Prevalidation of the approach

The validation of the proposed process model navigation metaphor, as with most information systems, can be subdivided into prevalidation, primary validation, and post validation. In this paper, we will be concerned with prevalidation. This first phase is carried out before implementing any prototype or running system [3].

We have used the Technology Acceptance Model (TAM)[4] for empirically prevalidating the navigation metaphor. TAM has been used successfully in many studies for more than two decades to test the potential adoption of new information systems by end users. Despite the fact that several other models have also been proposed to predict the future use of a system, TAM has captured most attention from the information systems community.

TAM suggests that *perceived usefulness* (PU) and *perceived ease of use* (PEOU) are beliefs about a new technology that influence an individual's *attitude toward use* (ATU) of that technology. In addition, the model postulates that the attitude toward using a new technology has a mediating effect on *behavioral intention* (BI) to use.

TAM uses a survey method to inquire end users about their perception levels (see sections 3.1 and 3.2). Afterwards, survey data is collected (section 3.3) and descriptive and inferential analysis techniques are performed, typically, using software packages for statistical analysis such as SPSS or SAS (section 3.4). The final step is to interpret statistical results to determine if a constructed model can predict that a new technology will be adopted, or not, by end users (section 3.4).

3.1 Instrument development

We constructed a survey (presented in Table 1) to measure perception levels. The table lists the four general constructs (PU, PEOU, ATU, and BI) and the 13 items/questions that were part of the survey. These items were recommended

Construct/Item & Measure		M
Perceived Usefulness (PU)		
PU1	I would find Navigation useful for business process management.	6
PU2	Using Navigation would enable to accomplish the task of process management more quickly.	6
PU3	Using process navigation would increase my productivity.	6
PU4	Using Navigation would make it easier to do my job to manage business processes.	6
Perceived Ease Of Use (PEOU)		
PEOU1	My interaction with the Navigation system would be clear and understandable.	6
PEOU2	It would be easy for me to become skillful at using the system.	5
PEOU3	I would find Navigation easy to use.	6
PEOU4	Learning to operate the Navigation system would be easy for me.	6
Attitude Toward Using Technology (ATU)		
ATU1	Using business process navigation is a bad idea (negative).	2
ATU2	Navigation makes business process management more interesting.	6
ATU3	Working with a business process navigation is fun.	6
ATU4	I would like working with a process navigation system.	6
Behavioral intention (BI)		
BI1	Assuming business process navigation would be available, I predict I would use it.	6

Table 1. The TAM-based survey students took (M=median)

in TAM's original article [4]. The items were validated in a pilot study involving two researchers and some wording was changed to make the survey specific for process navigation. All items were measured using a seven-point Likert-type scale with anchors from "Strongly disagree" (which mapped to 1) to "Strongly agree" (which mapped to 7). The survey included one item worded with proper negation. Items were shuffled to reduce monotony of questions measuring the same construct.

3.2 Setup and procedure

The subjects were students of the Department of Informatics Engineering, University of Coimbra. Before the experiment, subjects had a one semester introductory course on *Information Systems Management*. In the last week of classes, subjects were asked to give their opinion on the use of process navigation as a way to help them manage process models in the future.

The concept of a process navigation system was described to subjects using user interface (UI) mockups of the system drawn with Microsoft Powerpoint. The experimenter administered the survey to the subjects in class. Four UI mockups were shown to subjects (Figure 3 illustrates an example). One mockup was shown per slide. The functionality of the system was explained. The explanations given lasted 10 minutes in total.

After all participants had listen and understood the UI mockups, the experimenter shortly introduced the format of the survey and the survey was handed out. The survey was identical for all subjects. The subjects did not receive any textual description of the mockups.

As soon as every subject received the survey, they were asked to start filling out the questionnaire. The experimenter stayed in the room for the whole experiment assuring there was no collaboration among the subjects. Subjects could leave the room as soon as they were finished and every subject finished within 15 minutes. There were no limits on time.

Fig. 3. Example of a mockup shown to subjects based on the prototype implemented (see Section 4). Compared to the prototype, the mockups had additional elements which are marked with a star in the Figure; e.g. a bar showing KPIs, icons, and the visual outline of the signs for next steps was improved.

3.3 Subjects characteristics

A total of 14 Master degree students participated in the survey. It was held at the end of a 14 weeks semester. During the first four weeks of the semester, students were taught Business Process Management (e.g. state diagrams, workflow nets, Petri nets, tasks, activities, cases, control-flow, etc.). During the reminding of the semester, process models from ITIL (Information Technology Infrastructure Library) were also covered. At the time the survey was completed, students had a good knowledge of (business) process modeling and management. The sample consisted of 7% female and 93% male students with an age between 22 and 26 years. All the students (100%) were from Computer Science. No tests for colour blindness or visual acuity were conducted.

3.4 Analysis and findings

Prior to the assessment of the survey, guidelines for screening missing data and outliers were followed. The 14 usable questionnaires were examined for missing data. They showed a few missing values and the mean of existing values was used to generate replacement values for all the missing data. Due to the reduced number of subjects, no other tests were carried out.

Descriptive statistics showed that subjects have ranked the process navigation approach high in the items PU, PEOU, ATU, and BI. Most common answers to the questions pertaining these items included *I strongly agree*, *I agree*, *I somewhat agree*. Table 1 shows the median of the answers. Results suggest that subjects agree with the usefulness and perceived use of the metaphor since the median for most questions was 6, i.e. subjects have given the answer *I agree*. Subjects have also a positive attitude toward using a system implementing the metaphor, and believe that if such a system would exist they would use it.

We believe that these insights on the navigation metaphor are a good starting point to exploit its practical use by developing a first prototype. Nonetheless, this preliminary study needs to be replicated involving a larger number of subjects to be more statistically significant.

4 First prototype

The main objective of the prototype was to further study how mobile workers perceive a navigation system for processes. While in the TAM survey, the results were significantly influenced by the interpretation of the meaning of the navigation metaphor by subjects, the prototype allows us to study how the metaphor is perceived. For instance, we can visualize arbitrary cases to process workers on their Android powered device (cf. Figure 3) and study their reaction on it. Furthermore, we can show or hide context information, e.g. about the availability of data or the current 'traffic', and investigate the effect of its absence or presence on mobile workers. Different scenarios may be specified with a desktop application and sent on demand to connected Android front-ends. Consequently, all front-ends report the reaction of users (e.g. a direction sign was touched) back to the desktop application. However, since we first wanted to further investigate the effects of applying the navigation metaphor to process management on mobile devices, the desktop controller application does not (yet) comprise a workflow engine that automatically derives the next situation to be shown to users. Instead, the simulation is manually controlled and situations may be either defined dynamically or loaded from configuration files.

This basic simulation process is shown in Figure 4. It starts with the launch of the controller application on a PC which needs to be connected to the same network as the mobile devices (or which is reachable from the internet via its IP address). Then, the simulation front-end is started on Android powered mobile devices. Upon its start, the simulation front-end will try to establish a connection to the controller. Afterwards, the simulation supervisor may load a specific workflow case, update it to its specific needs and transmit it to connected front-ends. If a completely new situation is to be created, this may also be achieved by the supervisor using the controller application. It is important to note that the controller itself is not meant to be used as a solution for process modeling; instead, it allows for creating single tasks with a graphical user interface.

Upon receiving a specific case, the front-ends will set up the corresponding visualization. Subjects can introspect it, interpret the labels and descriptions, and make a decision about what to do next by interacting with their device (e.g. by touching the label of one of the alternatives shown on screen). This decision is then send back to the controller and visualized to the supervisor. It is then his responsibility to switch to the next situation in the workflow.

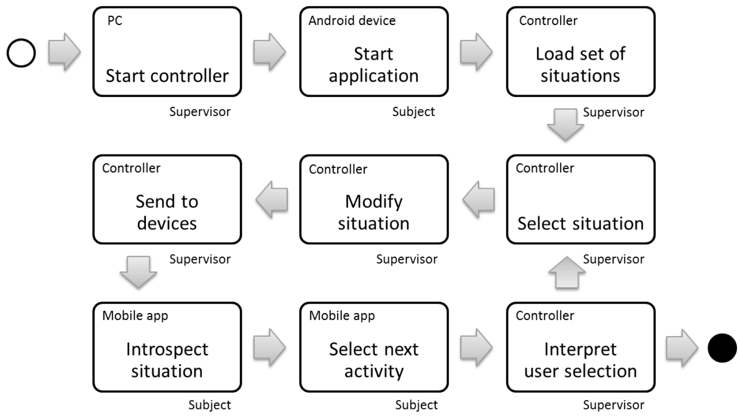

Fig. 4. Basic steps of the simulation as implemented by the prototype.

Even though both, architecture and the basic simulation process, were implemented in a very simple manner, they allow for studying the first important results relevant to the interaction of agents within a distributed, mobile workflow execution environment. First, the prototype shows our concept of how a workflow instance may be visualized following the navigation metaphor as described in earlier sections. It has some limited flexibility because of its current status, such as it only provides a detailed view on a specific case but not (yet) an overview of the whole process instance such that it supports taking single decisions but does not outline the route up to the destination. Second, it shows that the interaction between concurrently acting workflow agents need to be considered more closely. Even though agent selection and notification may be considered a standard feature of modern workflow management systems, the mobile scenario adds another level of complexity to the underlying problem in which agents may be temporarily disconnected from a central server instance. Work may be started and finished without being able to notify a server. Last but not least, the front-end only provides information about tasks to users. Real data is not yet transmitted. Accordingly, the controller receives notifications about the selection of a following task but no updates on the status of data or other workflow resources.

5 Related work

The applicability of the car navigation metaphor to workflow systems has been first discussed in [12]. In our work, we take one step forward and explore how it can be used to guide the development of mobile workflow solutions.

Hipp et al. [7] suggest to navigate through large process models using Google Earth. Compared to our work, the navigation is static. In other words, process instances are not visualized. The approach sees large processes as maps and the proposed system adds zooming functionalities. Effinger [5] developed a 3D Flight Navigator for visualizing process models. While the idea is interesting, so far, it only enables to represent models using a 3D view. Since process models are conceptual and logical representations, it is not clear what are the direct benefits of a 3D representation, except, possibly, the hierarchical visualization of sub-processes. Poppe and et al. [11] constructed a prototype for remote collaborative process modeling using virtual environments. The system relies on Second Life, a head mounted display, and enables the modeling of processes using BPMN. While this work contrasts with ours since we target the navigation of process models and instances, the results are relevant since preliminary data indicates that users interact well with virtual environments. Vankipuram et al. [14] rely on virtual world replay to visualize critical care environments. Our approach is distinct since we target the use of metaphors with a high degree of acceptance among end users for navigation applied to mobile devices.

Hackmann et al. [6] present a BPEL execution engine (called Sliver) which supports a wide variety of devices ranging from mobile phones to desktop PCs. The challenge of the work done was to demonstrate that mobile devices are capable of hosting sophisticated workflow/groupware applications. Leoni and Mecela [10], in contrast, describe a distributed workflow management system that runs on mobile devices (in this case on the Windows Mobile platform), that relies on BPEL for its execution logics. Following the traditional task list behaviour, the application only provides a screen for managing an assigned task.

6 Conclusion

Research indicates that new workflow paradigms for mobile devices can be inspired from the TomTom metaphor. Therefore, we have established an isomorphism between navigation and workflow systems which aggregates mappings in three categories: (1) topology of route networks, (2) the connectivity of maps, and (3) landmarks. Afterwards, we have conducted an acceptance evaluation to determine if end users would use a workflow system implementing a car navigation metaphor. The results were encouraging and led to the implementation of a first prototype. We believe that the isomorphism will enable users to reapply their knowledge from the domain of driving to the domain of workflow management and, thus, will facilitate the navigation of process models and instances. Our future work will focus on the implementation of additional features and to carry out a more complete system evaluation.

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