Flow-Driven Ambient Guidance

Using situated flows and embedded interfaces to guide people in pervasive work environments

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Abstract—**Effectively guiding people in complex and highly dynamic work environment requires advances in high-level declarative activity models that can describe the flow of human work activities and their intended outcomes, as well as novel user interface models for distributing guidance information across time and space. This paper describes a new line of research aimed at developing a new programming and human interface approach for pervasive systems based on high-level models of human activities, so-called *situated flows*, and mobile projector interfaces for uncovering task information embedded in physical environments.**

Keywords-Workflow, Pervasive Computing, Projected user-interfaces, Context-awareness, Adaptive systems, Guidance.

I. Introduction

Over the past years research in pervasive computing has demonstrated the potential of context-aware and proactive technologies for improving human work performance. Examples include systems for tracking and automatically recording task performance in industrial maintenance scenarios [7,9], measuring and informing workers about their exposure to equipment vibrations [6] and context-aware information capture and presentation at hospitals [1,5]. Pervasive work support systems make use of sensors and handheld and wearable devices to analyze work activities in real-time and to provide users with relevant and timely information pertaining to their work. Projecting in the future we can imagine that future work environments will be densely instrumented and be able to understand minute details of work activities and processes.

Yet while there have been great advances in sensing, great challenges for the development of pervasive work support systems remain: the first challenge relates to the lack of technology-independent and transferable models of human work activities. Activity recognition approaches are driven from the bottom up and use models that are highly dependent on algorithms and technologies; they are not suitable as *declarative* modeling tool for specifying organizational work processes. Workflow technologies based on BPEL [8] and other languages provide an interesting starting point for the development of declarative activity models, yet existing approaches lack features to express physical context (location etc) and are not suited for integration with activity recognition technologies.

The second challenge relates to the design of distributed and embedded user interfaces to effectively support people in demanding work environments such as hospitals and industrial plants. While there has been much progress on mobile and wearable device interfaces, the question of how to distribute information in a physical environment across time and space considering user context and work processes with the goal to maximize human performance has not yet been tackled. Yet, *ambient guidance* strategies, i.e. strategies for determining when, where and how to present work-related guidance in an environment is at the core of future pervasive work support systems.

In this paper we report our initial experience on a new line of research aimed at developing a new programming and human interface approach for pervasive systems based on high-level models of human activities, so-called *situated flows*. Situated flows model human work processes as a set of physical *actions* glued together by a plan (a set of transitions), which defines how activities should or could be performed to achieve a specific outcome. In contrast to traditional workflows, situated flows are *situated* and *context-aware*: they are linked to physical entities like equipment and people, moving with them through different environments, thereby reacting to and being influenced by their context. We use situated flows to drive the presentation and distribution of guidance information in pervasive work environments: body-worn context-aware projectors allow people to uncover flows and task information embedded in the surrounding physical environment. This provides for a seamless user experience where task information is virtually overlaid on physical entities it relates to.

This paper focuses on user interfaces and ambient guidance strategies. We first describe situated flows and then discuss user interfaces and guidance strategies; related research on situated flows is being carried out by project partners [10,11,12].

II. Situated Flows

A situated flow (*flow*, for short) is a high-level programming language for modeling real-life processes and human activities. It consists of a set of *actions* glued together by a plan (a set of *transitions*), which defines how actions should be performed to achieve some goal under a set of constraints [10, 11].

Actions model physical activities of people or digital processes. For example, for a nursing home scenario we identified situated flows that model the daily rounds of a nurse in a hospital, the daily care schedule of a patient and the operation procedures or handling instructions of various pieces of medical equipment (Figure 1).

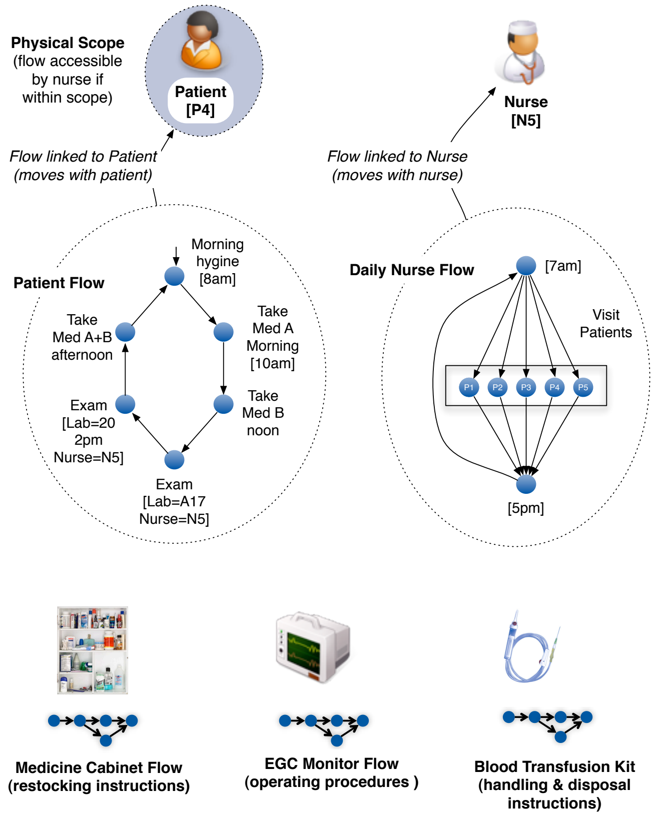


Figure 1. Situated flows in Nursing Home Scenario. Patient flow, nurse flow and three equipment flows.

Situated flows are closely related to classical workflows [8], yet they differ in that they are situated and context-aware: they are (logically or physically) linked to real-world entities like people and objects, being carried by them or moving with them through physical environments. Flows are executed in parallel to the real-world actions they describe: when an action that is described in a flow is performed in the real world (by a person), the flow progresses one step.

From a human point of view, situated flows define *opportunities for action*. A flow embedded in an object or room defines tasks and actions that can or should be performed *with the object* or *in the room*. An action can be a *physical action* such as dispensing medication or a *digital action* such as turning on a machine. Assuming an organization has defined flows and linked them to entities, people and locations (thereby creating a physically dispersed business process model), the key question we investigate is: *How can a person discover flows in the surrounding physical environment and act upon them?* Alternatively phrased: *How can situated flows be used to effectively guide peoples' actions and help them achieve work-related goals?*

Our solution to this question consists of two components: mobile projected interfaces for uncovering task information embedded in physical environments and guidance strategies for deciding which information should be accessible and when, where and how it should be presented in the environment.

III. Projected Interfaces for Ambient Guidance

Designing user interfaces for ambient guidance systems raises considerable design challenges due to i) peoples' primary engagement in physical activities, ii) mobility support, and iii) temporal and spatial value of information**.** Thus traditional handheld interfaces and emerging distributed public displays are not well suited. Conversely, pervasive computing has instigated a transformation of our environment into an ecological synergy of networked smart objects [2,4,13]. This enables us to distribute and embed flows into physical workplace objects and to utilize them as a natural interaction points for ambient feedback and guidance. The recent progression of mobile projectors and projector phones [3] provide an effective solution for realizing object and environmental interfaces. Fundamentally, mobile projection technology overcomes the output limitation of flow-embedded objects by turning them into dynamic information displays.

Accordingly we have adopted a combination of embedded flows and wearable camera/projector devices as foundation for ambient guidance system. Users wear a camera/projector system that visually interrogates the surrounding environment and triggers contextual information projections on the appropriate surfaces and objects. Our current implementation uses 2D bar codes to identify objects and projection surfaces. Figure 2 shows the current prototype of our system, where a flow-enabled medicine tray (left) and workplace surface (right) present contextual ambient guidance to the user.

IV. Ambient Guidance Strategies

Flows represent context-specific prescriptions for how activities and tasks are supposed to be done or how equipment is to be operated. Mobile projection interfaces make it possible to expose activity and task information to users. Yet in order to effectively guide people, i.e. help them achieve goals defined by flows, it is not enough to simply present people with every single task they come across. Effective guidance requires a *guidance strategy* that defines:

Figure 2. Left: Guidance Interface projected on medication tray. Right: Belt-mounted mobile projector with wall-projected interface.

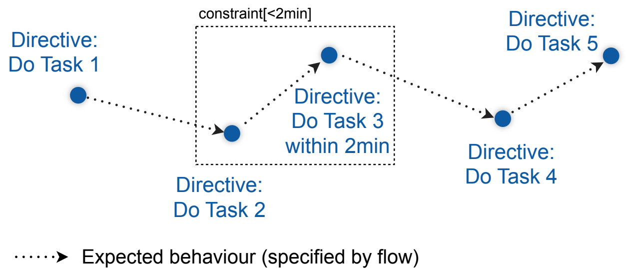


Figure 3. Directive Guidance

- Which tasks and activities are exposed to people (by selecting flows and activities from within the local scope of the user)
- When and where guidance information is presented.
- How to visually present guidance information.
- How to cope with situations in which people do not follow flow descriptions.

In order to cope with disparate requirements of application domains we developed two levels of generic guidance strategies.

A. Directive Guidance

Directive guidance (Figure 3) is a strategy that presents users with just-in-time notifications (directives) of the next activities to be done (as defined by the flow). To be precise, directives are generated and presented to users just before an activity has to be performed. For example, in a hospital scenario, before and during preparing medicines for a patient, it is beneficial to provide an updated (if any) prescription guide to the nurse. This could be useful for certain circumstances, e.g., immediately after the nursing shift change.

B. Corrective Guidance

Corrective guidance (Figure 4) is a strategy that assumes that people have satisfactory understanding of what they have to do and that they don't require constant reminders. Instead this strategy only presents users with guidance information when the flow system detects significant deviations from the plan. This is visualized in Figure 4: a *flow corridor* defines how much an actual activity may deviate from the one prescribed by the flow. If an activity falls outside the flow corridor, the flow system issues corrective feedback to inform users of the deviation and motivate the user to follow the plan as described. For example, in a hospital scenario, if a nurse accidently overlooks or delays a scheduled checkup or medication of a patient, the guidance system kicks in with a reminder. In an industrial scenario, if a worker performs critical operations in the wrong order and thus incurs a safety risk, the guidance strategy determines appropriate counter measures (for example undoing of already taken steps) and decides how to inform the worker. The corrective plans can be dynamically generated from the flow model and current flow state.

Directive guidance is a suitable strategy in training scenarios or when work activities must be performed exactly as described (for example for safety reasons). Corrective guidance, on the other hand, is more suited for expert users and relaxed application domains, where deviations are to be expected or can be tolerated.

V. Discussion

In the previous sections, we have presented the primary building blocks for facilitating ambient guidance in workplace environment. Situated flow accommodates the structural foundation for instrumented smart objects to actively guide people leveraging a projected user interface multiplexed by context-aware guiding strategies. Currently, we are exploring the application of such guidance system in a hospital to support the daily activities of nurses. As mentioned in the earlier sections, situated flows distributed across the instrumented environment model the activities of the nurses, and a fine-grained activity recognition system [7] works atop these flows to provide accurate contexts that trigger the guidance. In the current prototype nurses are assumed to carry a projector camera phone that act as the primary interaction channel for the system, i.e., depending on the context of the nurse (e.g., state of the flow, current activity, location, position, etc.) information notification is projected. Our early insights with the guidance system open up a range of interesting research issues that need thorough investigations to formulate a concrete understanding on the impact of such ambient guidance system in critical workplaces. Some of these issues inline with our future work are discussed below.

A. Discovery and Association of Flow

The fragmentation and distribution of situated flows across time and space in multitude of instrumented smart objects put forth a range of issues related to ambient guidance. For instance, at this moment it is not clear what defines the scope of a flow and how this scope contributes to the discovery and association of flows to smart objects and people, i.e., how to selectively present a set of tasks and associated guidance to users? What context parameters determine the granularity of this exposition of activity? What degree of autonomy is optimum? Our immediate future avenue of work includes a deeper investigation of these issues from a user interface perspective, and to gain insights on the influence of situated flow discovery and association mechanisms in interface design.

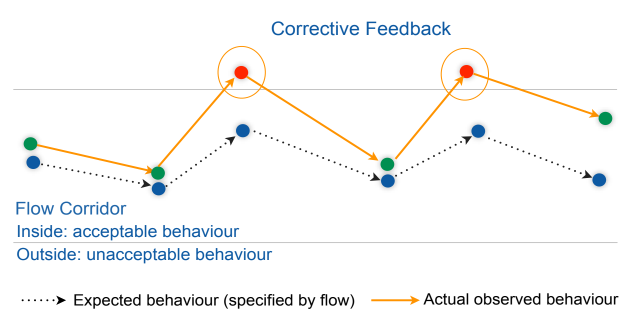
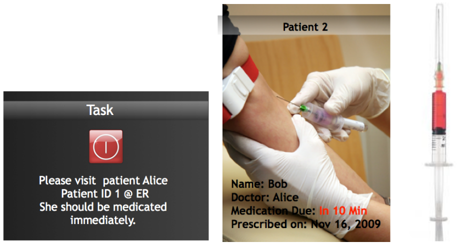


Figure 4. Corrective Guidance



Text Image Symbol

Figure 5. Three alternative modalities for guidance interface.

B. Spatio-Temporal Information Distribution

Mobile projected interface is an exciting emerging technology that has potential to bring substantial advancement in building pervasive interfaces distributed across physical spaces. However, there are several design and usability issues that need to be addressed to fully reap the benefits of this technology. Our early experiences with the mobile projected interfaces in guiding people exposed some of these issues. It is essential to have a formidable understanding on where to project information, when and for how long? For example, guidance notification could be projected on the nearest flat surface, or on the floor, or on the object that the user interacting with. It is not clear what parameters contribute in determining the target projection area and what degree of control users should have to overwrite system's decisions. Currently, we are exploring these design questions to frame design guidelines for projected interface in workplace environment.

C. Presentation Modalities

Another interesting design aspect is the degree of information exposition. Too much information potentially degrades convinces of the assistance. It is essential to find the appropriate balance between the perceptual complexity and information overload, making sure guidance is provided in an appropriate way. In our experimental setup, we have designed three levels of presentation (Figure 5): i) textual, ii) pictorial with embedded text and iii) symbolic. The correct interface depends on several contexts, i.e., complexity and type of the activity, importance of information, environmental attributes, e.g., brightness, etc. We are currently working on defining a set of context parameters that can effectively derive the right type of interface.

D. Flow Violations

Our two generic guiding strategies were formulated to cope with the disparate dynamics of workplaces. Demanding workplace environment requires active adaptation to meet the dynamics of the circumstances that emerges due to the temporal and spatial constrains imposed temporarily and periodically. The subsequent guiding strategies must handle such dynamics. For example: flow violations are not automatically bad; they must be handled with an understanding of the application domain. At a chemical processing plant, for example, flow violations might be considered serious breaches of work procedures that can endanger health and safety of personnel; in less dangerous work settings flow violations might be the norm as experts have developed tacit work practices that are best suited to achieve results even though they may violate stated guidelines or rules [6]. In the future, we would like to further explore the design space of the guidance strategy in cross-domain applications.

VI. CONCLUSION

This paper discussed our initial experiences with a flow driven ambient guidance system for a demanding workplace environment. We presented the fundamental concepts and an early stage prototype and identified key research issues as an agenda for future research.

Acknowledgment: This research has been funded by the European Commission (EC 213339 ALLOW).

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