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# Activity-Centric Configuration Work in Nomadic Computing

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**Figure 1:** Clinicians discussing patient cases in the nurse station

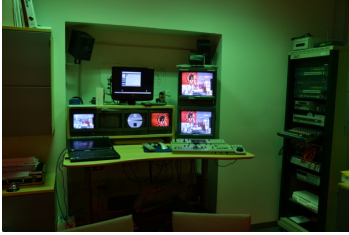
Submitted to the CHI2014 - HCI Research in Healthcare: Using Theory from Evidence to Practice

## Abstract

The workflow in hospitals can be described as *nomadic*, which means that clinicians roam through the hospital while interacting with a large number of people and information related to different patient cases. Over the years, more device types (such as mobile devices, large interactive whiteboard) have been introduced into this workflow to support mobility and coordination. However, most of these devices and systems are intrinsically disconnected from each other, forcing clinicians to manually *reconfigure* them to match the active work setting according to the situation. In this paper, we describe an activity-centric approach to this multi-device configuration problem that is grounded in activity theory.

## Introduction

The workflow of clinicians in a patient ward can be described as *nomadic*. In addition to sitting in an office or other fixed location for managing, archiving and preparing patient information (as seen in Figure 1), clinicians also roam through the hospital while doing their work [2]. This work typically includes collaborations with a large number of people and usage of physical tools and computing devices that are spread over multiple locations. Clinicians often move from one location to another while interacting with both mobile and stationary tools and devices, such as desktop computers (Figure 2), large interactive



**Figure 2:** Desk with several screens used to monitor ongoing surgery.



**Figure 3:** Large interactive display used for coordination on all patients in the ward.



**Figure 4:** Mobile device used during patient interaction e.g. for giving medication.

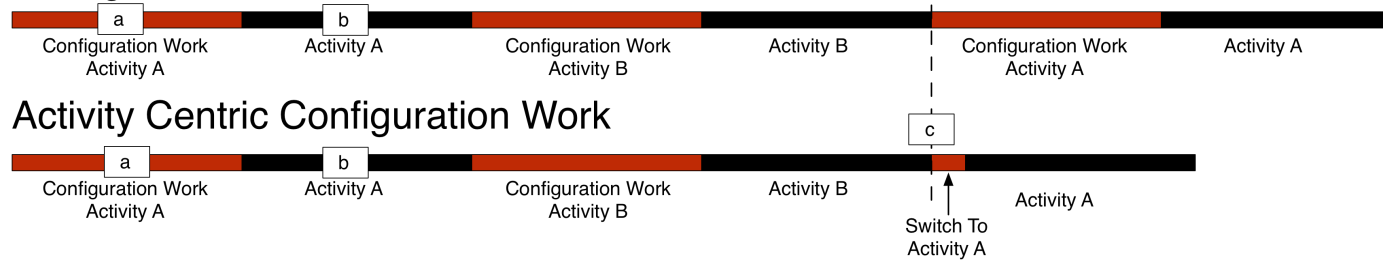
whiteboards (Figure 3) and mobile devices (Figure 4). Our observations in different patient wards show that despite the ubiquity and importance of these tools for the information flow in the hospital, most of these tools are not designed, tailored or suited for this nomadic use, thus resulting in a mismatch between the functionality of the system and the actual work done by the clinicians. Fundamentally, all these different systems and devices are intrinsically disconnected from each other, forcing clinicians to manually *reconfigure* the active work setting according to the situation. This results in work interruptions, information fragmentation and a disconnected workflow crossing several information resources. Furthermore, there is little support for the ongoing collaborative context, situation or specific role of the device. We describe this problem as the *multi-device configuration problem*, which refers to the effort required to *control, manage, understand* and *use* information, applications and services that are distributed over all used devices.

Despite a growing number of new electronic health systems, most solutions do not transcend the traditional application and file-oriented paradigm, resulting in a preservation of the mismatch between the work done in hospitals and the systems supporting this work. Our prior work [1] has uncovered that work in hospitals can be organized and structured using the *activities* of clinicians as a central computational construct that encapsulates configuration, communication and coordination processes in day to day hospital work. However, the important role of computing devices as tools in this web of activities is often not very explicit. In this paper, we describe an activity-centric approach to this multi-device configuration problem grounded in activity theory.

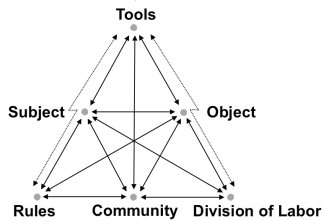
## Theoretical Background

Activity theory (AT) is a psychological framework that describes human activity as a relation between the subject (S) (human or group that acts in the world), object (O) (which is acted upon and motivates the activity) and the community (C) (or social strata in which the activity is engaged) [3]. The motivation of an activity is projected and reflected into an outcome, which is the contribution of an activity. The S-O-C relation is mediated by tools, rules and division of labour (Figure 6). First, *tools* provide the subject with a way to act in the world. They externalize the act in the world through enactment and are shaped by affordance and resistance. Second, *rules* define how the act of the subject is embedded in the social context. It socializes the act in the environment, culture and world. Third, *division of labour* structures the relation between the social strata and the object of the activity. It links the distribution of work among community to the hierarchical motive towards the object. Activity is not a fixed structure but a dynamic hierarchical interaction between the activity itself driven by motivation, conscious goal-directed actions and unconscious operations that are performed when certain conditions are met. In summary, activities are why we do something; actions are what we do it; and operations are how we do [6]. Engeström [4] categorized four fundamental processes (Figure 7) that are interwoven into this hierarchy. These processes are: (i) production, (ii) consumption, (iii) exchange and (iv) distribution. As activity theory moves into its third generation, it has become clear that the unit of analysis is expanding from an individual analysis to a global analysis that comprises not only the individual, the community, and the artefacts but also the interconnectivity between activity systems. The focus is on networks of interacting activity systems, the dialogues between these systems and the multiple perspectives of these networks of activity [4].

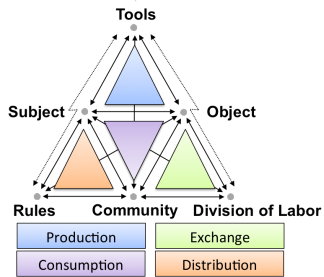
# Configuration Work



**Figure 5:** Configuration work (a) is the effort required to set-up an environment for a specific activity (b). Activity-centric configuration work however reduces the resumption lag by enabling users to store and retrieve activity configurations across users and devices (c)



**Figure 6:** The basic components of an activity.

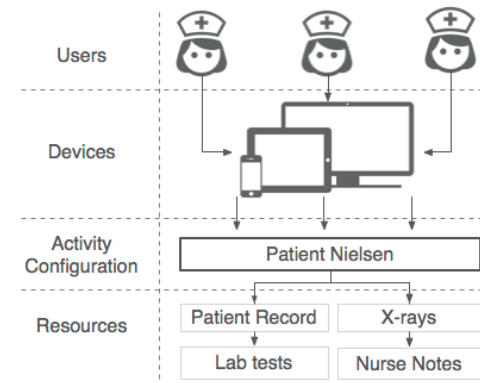


**Figure 7:** The fundamental processes inside an activity system

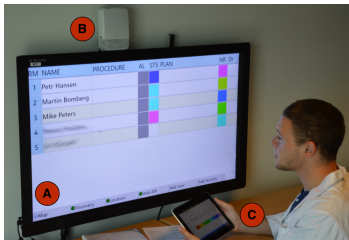
## Activity-Centric Configuration Work

We define *configuration work* as the amount of work required to locate, prepare, arrange and set-up all necessary resources required to complete the objective of an activity. It is the total effort required to *control, manage, understand* and *use* information, applications and services that are distributed over all used devices and users. We extend this to the notion of *activity-centric configuration work* through a conceptualization of configuration work from an activity theoretical point of view. Since activity theory uses activity as first class analytical object, we frame the use of computing devices as *tools* that are part of *activity systems* that are produced, consumed, exchanged and distributed (Figure 7) during nomadic work. Because information on computing devices are often *boundary objects* [7], meaning they can fulfil many different purposes as part of different activities, they can be both in a stable or unstable state. The *stability* of the state refers to the appropriateness of the configuration in terms of goals of the activity system. In case either the configuration of the device does not match the goals of the activity or the device has become part of another activity system, the tool becomes unstable. This requires users to perform configuration work to re-purpose the tool to match the goal of the activity. When, for example, the incorrect patient data is shown on a mobile device, the clinicians' focus drifts away from the main activity (care for the patient) to configuration work, in order to set-up the device to visualize the information of the correct patient.

One fundamental approach to reducing the mental overload of switching between ongoing work on different devices is to provide meaningful computational representations of real activities. We hypothesize that by allowing users to interact with computation representations of real-world activities, switching between device configurations will be more efficient, more effective and will support users' mental model in a multi-user and multi-device environment. Activity-centric computing uses the notion of *activity configuration* (Figure 8) as a description of a work context (including files, applications and other meta information, coordination practices and communication tools) that is a reflection of the real ongoing activity.



**Figure 8:** An activity configuration aggregates a set of computational services, data resources, and users who can access the configurations through devices.



**Figure 9:** The SmartWard system consists of a large interactive whiteboard to display shared information on patients registered on the ward using RFID (A), a location tracker used to detect which patients are at the ward or in surgery (one node visible in B) and a tablet (C) used by doctors and nurses for more detailed information on the patient.

By explicitly using activities as fundamental first-class computational structures, these activity-related configurations or tools states can be (i) constructed, (ii) shared and (iii) restored across devices thus reducing the amount of configuration work required to change ongoing work. Compared to traditional computing systems, activity-centric computing still requires a configuration step in which users (co-)create or share a new computational activity as part of an emerging real-world activity (Figure 5). However, because of the activity configuration the resumption lag – the time required to switch to another work setting – is reduced as the activity representation can easily be restored as one working context. In a clinical context, for example, all patient-related information can be structured into computational activities that are part of the same distributed activity system. This allows devices to be simply *plugged* into this system by leveraging the existing patient configurations and work context (e.g. nurse notes) as initializer for the new device.

### SmartWard

A concrete application of the theoretical concept discussed above is the *Smartward* (Figure 9) system. SmartWard is an activity-centric distributed context-aware patient management and information system designed to support multi-device location-aware collaborative workflows in patient wards. SmartWard supports patient management across large interactive displays (Figure 9 A), tablets (Figure 9 C) and desktop computers, and uses an ultrasound location tracker for location-aware services (Figure 9 B). The SmartWard system is designed as an *activity system* [5] in which all information and coordination tools are abstracted into activity configurations that reflect patient cases. These activity configurations can be created, accessed, modified,

distributed and shared across different device types showing different levels of information granularity. In contrast to traditional device use (like in Figure 2, 3, and 4), devices can be automatically configured for a specific clinician using existing activity configurations and context (such as the type or location of the device; or the role of clinician in a specific patient case). Devices are thus *portals* into a shared activity-centric information space in which information is organized in thematically logic abstractions of daily work at a patient ward.

To explore the usefulness and feasibility of the approach in a clinical setting, we conducted a scenario-based field evaluation of the entire SmartWard system. The study indicated that cross-device activity-centric patient information provided clinicians with an automatic redundant and detailed distributed coordination mechanism. They could for example easily double-check information entered by other clinicians or themselves across the different devices to verify correctness. Structuring working data related to a patient case in one activity that could be moved between devices provided clinicians with a quick and ad hoc overview of work in progress. Furthermore, the explicit process of dragging and dropping activities between the large display and personal tablet added an additional verification that the correct patient data was shown. Finally, location-based activity suggestions were considered as very useful as they reduce the configuration overhead and can potentially avoid errors in selecting patient information.

### Acknowledgements

This work was supported by the EU Marie Curie Network iCareNet under grant number 264738.

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