

Towards a Formal Description of Context

Holger Kenn and Hendrik Witt and Tom Nicolai

University of Bremen
Center for Computing Technologies
{kenn,hwitt,nicolai@tzi.de}

1 Introduction

An important aspect of wearable computing is the fact that users do not focus their attention exclusively on the wearable computer but are often occupied by other tasks. Therefore, implicit interaction is desirable because it avoids constant user attention. The information that is needed to support such interaction is usually called context information. To establish context, a wearable device needs to observe the user and its environment through sensors to afterwards interpret this information to enable implicit interaction.

Current research on context is pointing in many directions. The Context Toolkit[1] aimed to be a reusable solution to handle context in a distributed infrastructure. In [2], Gellersen et al. presented several prototypes that use data from multi-sensors instead of a simple sensor. Others use context for building intelligent user interfaces like Bolt's Pioneer work in [3]. Because of the different notions of context and the obvious lack of an precise definition, this paper is an attempt to define context in a more formal way.

2 Determining Context from Sensors

The task of determining context from sensors is basically divided into two different aspects: The definition of a context model and a contextualization process that matches a given set of sensor values to a valid description in the context model. A *context model* consists of all existing context descriptions of all sensors. Thus, we have to define its components to formally describe the contextualization process.

We expect an environment with the presence of sensors $s \in \mathcal{S}$. Sensors observe a property of the environment and provide sensor values in regular time intervals with a finite number of possible outcomes. A *sensor* is defined as a triple of time \mathcal{T} , the domain of the sensor values \mathcal{D} and a sensor function \hat{s} that gathers sensor values: $s = (\mathcal{T}, \mathcal{D}, \hat{s})$, $\hat{s} : \mathcal{T} \rightarrow \mathcal{D}$. Each sensor can provide a *time series* σ of the last p sensor values, starting from the current time t_{now} , which forms a time window: $\sigma_s = (\hat{s}(t_{now-p}), \hat{s}(t_{now-(p-1)}), \dots, \hat{s}(t_{now-(p-(p-2))}), \hat{s}(t_{now}))$. With the existence of time series σ , we can define the description of contexts: An *atomic context description* \mathcal{C} is a subset of \mathcal{D}_s^p , which is the set of all time

series of sensor values of length p of a sensor $s \in \mathcal{S}$:

$$\mathcal{C}_s \subseteq \mathcal{D}_s^p := \prod_{i=1}^p \mathcal{D}_s \quad (1)$$

A *composite context description* is a logical expression that uses atomic context descriptions for its own definition. To define the *contextualization process* we use the semantic of propositional logic for composite contexts and an interpretation function $\mathcal{I} : \mathcal{C} \rightarrow \{0, 1\}$ for the interpretation of atomic contexts as shown in equation 2. The interpretation of junctions in composite contexts is equivalent to those used in propositional logic.

$$\mathcal{I}(\mathcal{C}_s) = \begin{cases} 1, & \sigma_s \in \mathcal{C}_s \subseteq \mathcal{D}_s^p \\ 0, & \textit{otherwise} \end{cases} \quad (2)$$

3 Distributing Context Processing Tasks

On wearable computers, some sensor processing algorithms can not be efficiently implemented due to CPU limitations. An option is to offload sensor data processing to an external computing infrastructure, but has the drawback of an increasing communication load. By using a formal context description, complex context processing tasks can be spilt easily between junctions to be separately computable. From the communication load perspective, context processing should be performed always in a network node close to the sensor to save bandwidth, because in general encoded formal context descriptions are smaller than encoded sensor data.

4 Summary and Outlook

In this paper, we present a formal description of context based on sensor time series. This approach is powerful enough to serve as a general model for many context processing approaches and especially for analyzing the properties of distributed context processing. Due to the current assumption that sensor values are always precise, we will extend our model in the future to derive context information from sensor values even if they are erroneous. To solve this problem we will use confidence levels as a metric to describe the certainty of recognized contexts.

References

1. Salber, D., Dey, A.K., Abowd, G.D.: The context toolkit: Aiding the development of context-enabled applications. In: CHI. (1999) 434–441
2. Gellersen, H.W., Schmidt, A., Beigl, M.: Multi-sensor context-awareness in mobile devices and smart artifacts. *Mobile Network Applications* **7** (2002) 341–351
3. Bolt, R.A.: "put-that-there": Voice and gesture at the graphics interface. In: SIGGRAPH '80: Proceedings of the 7th annual conference on Computer graphics and interactive techniques, ACM Press (1980) 262–270