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REPORT

State of the Art in using Context in Mobile Information Systems

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SINTEF ICT

Cooperative and trusted systems

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ABSTRACT

This report is a State of the Art of how adaptation to context may influence the workings and the interface of mobile information systems.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	ICT	IKT
GROUP 2	Human Computer Interaction	Menneske-maskin-interaksjon
SELECTED BY AUTHOR	User Interface Adaptation	Brukergrensesnitt-tilpasning
	Mobile Users	Mobile brukere
	Context	Kontekst

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1 Introduction

This document contains the results of a State of the Art survey of how context awareness (Schilit 1994) in mobile information systems may be modelled and utilized for improving the interface or the general system behaviour. Context awareness is a central challenge for mobile and pervasive application environments.

The survey is an expansion on the context awareness point chapter in (Vraalsen 2005).

2 Usage of Context

Context may be defined (Dey 2001) as:

- “...**any information that can be used to characterise the situation of an entity.** An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.”

And a system is *context-awareness* if it:

- “...**uses context to provide relevant information and/or services to the user,** where relevancy depends on the user’s task”.

There are however proponents of the idea that context cannot be an objective set of features, but rather an emergent result of activities and practices called *embodied interaction* (Dourish 2004).

Since the context changes fast in a mobile setting, it is especially important to take heed of this when designing such systems.

There are several ways of utilizing context in a mobile information system (Akselsen, Finnset et al. 2002) (Dey 2001):

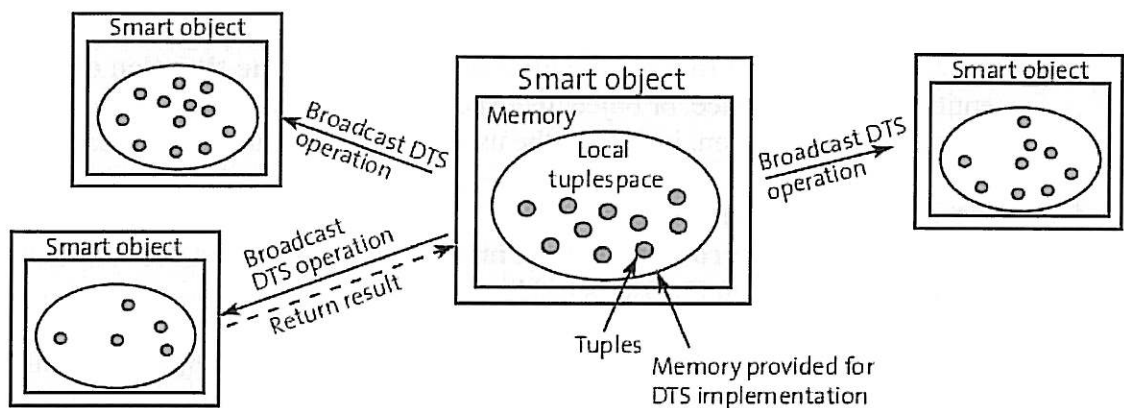
- 1) Adapting the **user interface** and the options presented according to the current context. E.g turning on backlight when in darkness. $UI = f(CTX)$
- 2) Adapting the information **content** to the current context. This is tantamount to using the current context as a continuously updated query which acts as a focal point for filtering out the most relevant options for the user, thus alleviating him/her from having to explicitly selecting the right options manually. (Rahlff 2004) (Rahlff, Rolfsen et al. 2001) (Hong and Landay 2001). A specific kind of such systems is the memory-aiding/life-logging systems (Werkhoven and Karssen 2004). $INFO = f(CTX)$
- 3) Using the context to initiate context-sensitive **communication** (Schilit, Hilbert et al. 2001) $COMM = f(CTX)$
- 4) Matching QoS demands of the interplay of several devices with current context in order to **utilize the available internal resources better**, such as memory and bandwidth (Hallsteinsen, Floch et al. 2004). $RES = f(CTX)$

3 Different Context Models

A good survey of the different ways of modelling context can be found in (Strang and Linnhoff-Popien 2004) although with a strong bias towards ontology based models. The categories used in this document mirrors that structure.

3.1 Key-Value-Pairs Models

These models representing pairs of $((key_1, value_1), (key_2, value_2), \dots)$ are also called *tuple spaces*. They are simple, but have problems expressing complex relationships. Examples of middleware supporting such models can be found in (Christine Julien 2004) and (Siegemund 2004) where a language *Smart-Its Context Language* (SICL) has been defined and used.



Distributed tuplespace implementation (Siegemund 2004)

```

1: smart object name;

   %{
4: C declarations
   %}

   /* sensor statements */
8: define [remote|local] sensor name {
9:     tuple type declaration;
10:    sensor access function;
11:    sensor access policy;
12: };

   /* tuple transformations */
15: func1(arg11, ..., arg1m1), ..., funcn(argn1, ..., argnmn)
    tup1 < field11, ..., field1p1 > + ... + tupq < fieldq1, ..., fieldqpq >
    → tupq+1 < field(q+1)1, ..., field(q+1)pq+1 >;

   /* adaptation rules */
20: tup < field1, ..., fieldp > → func(arg1, ..., argn);

   %%

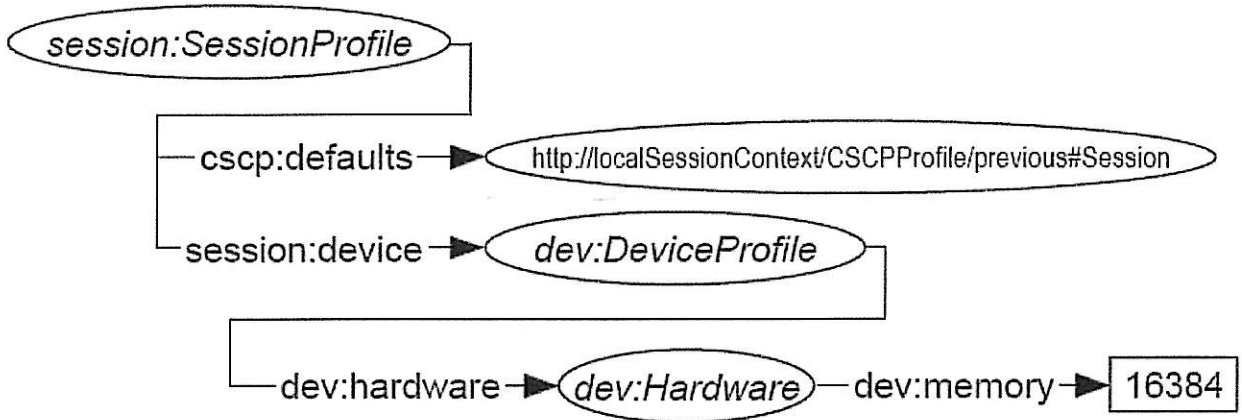
24: C code

```

Basic SICL program structure for a Smart Object (Siegemund 2004)

3.2 Markup Scheme Models

Some context modelling languages are based on markup languages, such as RDF. One of these is *Comprehensive Structured Context Profiles* (CSCP) (Held, Buchholz et al. 2002).



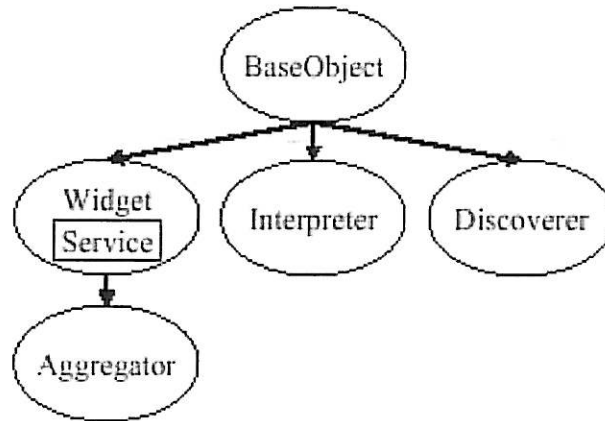
Example of RDF Graph notation (Held, Buchholz et al. 2002)

3.3 Graphical Models

This includes classic UML modelling, see (Tazari, Grimm et al. 2003). These may use model driven approaches (MDA) to translate the abstract models to code running on the different devices.

3.4 Object-Oriented Models

These models can be found e.g. in the *Context Toolkit* (Dey 2000) (Dey, Salber et al. 2001). They support the standard mechanisms of polymorphy and inheritance.



Example object structure

Widget Class	Activity
Attributes	
Location	<i>Location the widget is monitoring</i>
Timestamp	<i>Time of the last change in activity level</i>
AverageLevel	<i>Activity level (none, some, a lot) averaged over a user-specified time interval</i>
Callbacks	
ActivityChange (location, AverageLevel, timestamp)	<i>Triggered when the activity level changes from one level to another</i>

Example: Attributes and callbacks of the *Activity* widget from (Salber, Dey et al. 1999)

3.5 Logic Based Models

Here the models use a kind of “contextual Prolog” where higher order context abstractions are forward-chained from basic context measurements using inference as in (Ranganathan and Campbell 2003).

1. #People(Room 2401, “> =”, 3) AND Application (PowerPoint, Running) => RoomActivity(2401, Presentation)
2. #People(Room 2401, “> =”, 1) AND Application (MPEG Player, Running) => RoomActivity(2401, Movie Screening)
3. #People(Room 2401, “> =”, 3) AND NOT $\exists_{\text{Application } x}$ Application(x, Running) => RoomActivity(2401, Meeting)
4. #People(Room 2401, “=”, 1) AND Application (Visual Studio, Running) => RoomActivity(2401, Individual Development)
5. #People(Room 2401, “=”, 2) AND Application (Visual Studio, Running) => RoomActivity(2401, Extreme Programming)
6. #People(Room 2401, “=”, 0) => RoomActivity(2401, Idle)

Example of rules for inferring Room Activity Contexts (Ranganathan and Campbell 2003)

3.6 Ontology Based Models

These more sophisticated models may use semantic web languages for defining and publishing a context ontology, such as in the *Context Broker Architecture (CoBrA)* (Chen 2003).

Understanding Scenarios of Mobile Context

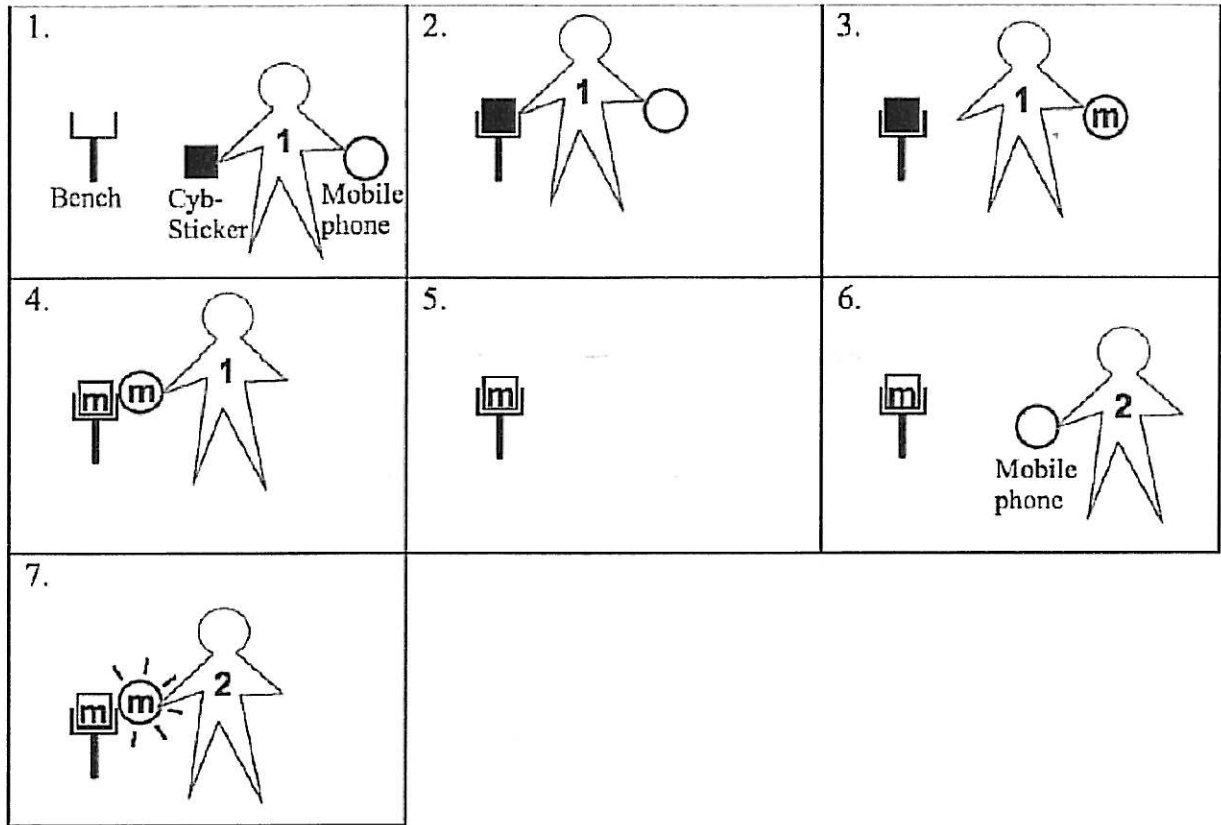
When creating use cases for mobile systems one may use *storyboards* at different levels of detail to communicate what the system does, or what the context of use actually is.

One such use of storyboards is *Picture Scenarios* (Pedell and Vetere 2005) where photos and talk bubbles illustrate the workings.



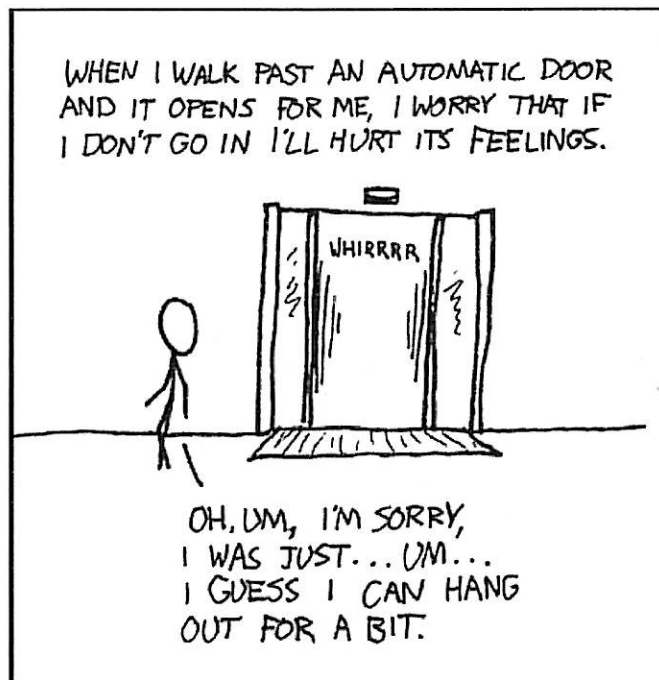
Example Picture scenario: Parallel scene (Pedell and Vetere 2005).

For more detailed modelling of system behaviour encompassing several devices and detectable tokens, (Dahl 2007) has created a very useful and simple visual formalism which we may call *Dahl notation*. It abstracts the different systems and makes it easier to create cartoon-like illustrations of how the system responds to changing context. The notation contains visual elements for users, devices, tokens, zones and differentiates between mobile and stationary uses. This notation can be seen as an in-between between picture scenarios and more detailed UML modelling.



Example of Dahl notation: Tagging read/write with mobile phone (Dahl 2007)

Some visualizations of interactions also lend themselves easily to the popular press:



A UbiComp scenario of a different kind...

4 Context and the UI

Traditionally the field of context-awareness has been following a technology driven approach. It is therefore important to address the user-centric side of the systems: the needs and desired behaviour of such systems.

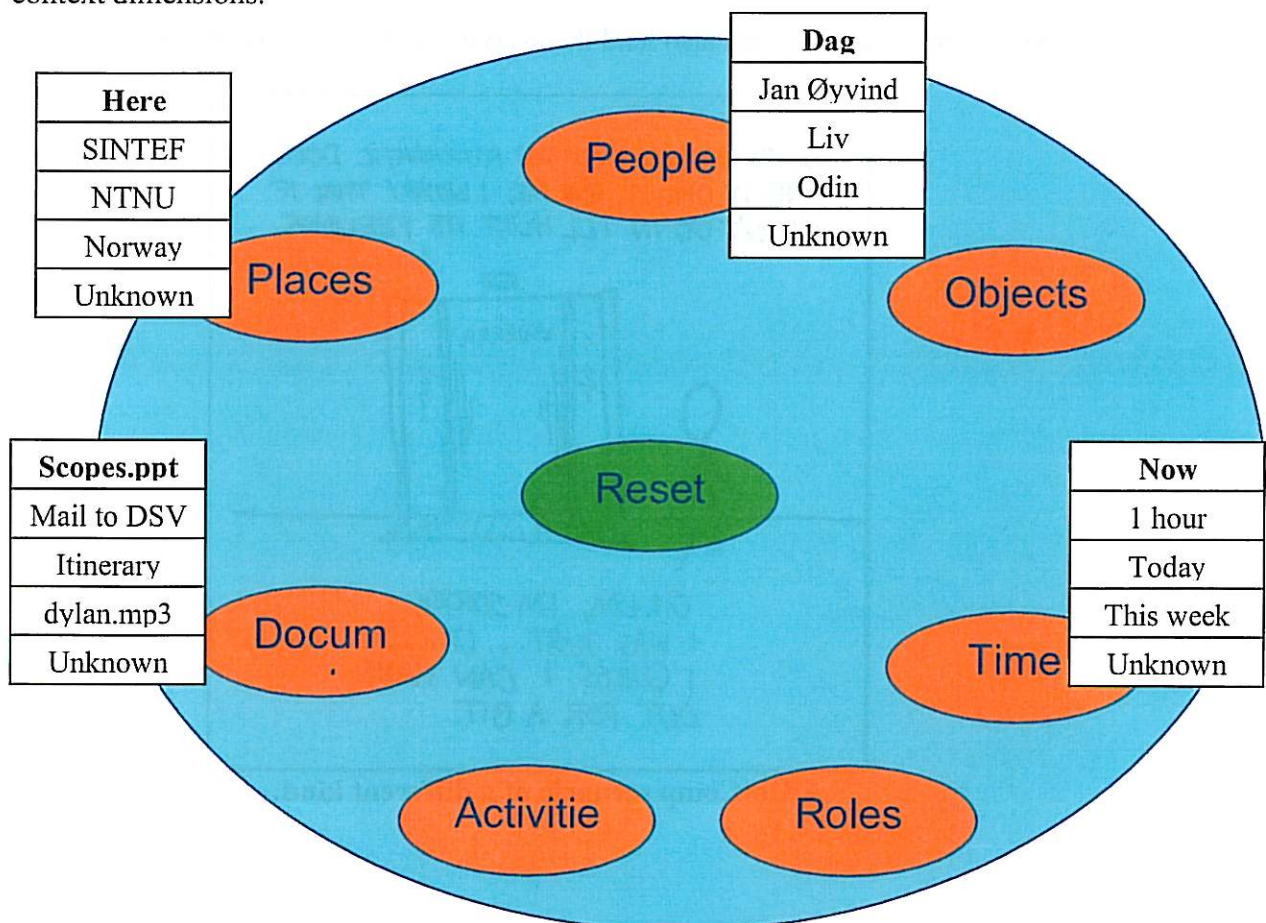
The adaptation of the system to the user activities and context changes will show up for the user as:

- Context reflection - basic context visualized (e.g. net coverage, clock etc)
- Processed context (e.g. assumed position on map, or augmented reality use)
- Available services.
- Changed system behaviour (video turning B/W e.g.).

These types will now be detailed and exemplified further.

4.1 Context reflection

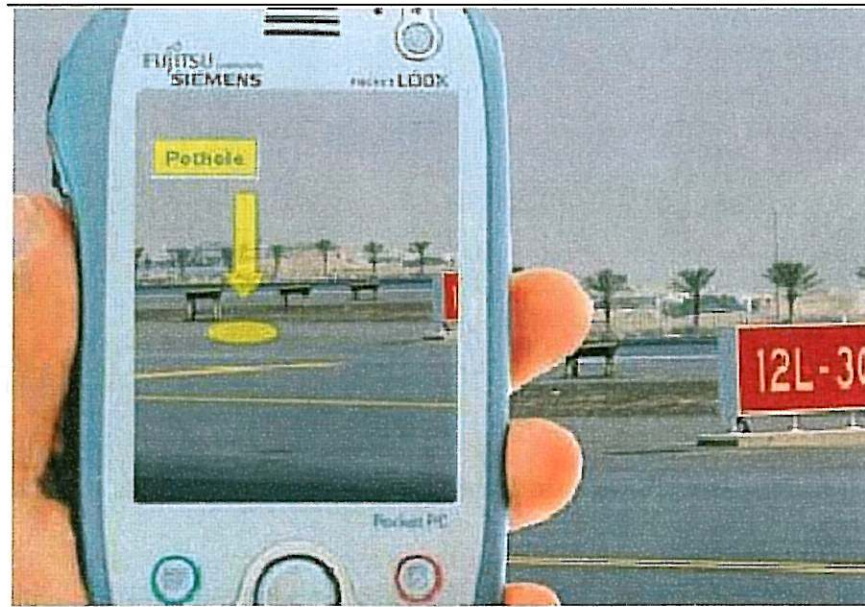
In what I have chosen to call *context reflection systems*, the current context is merely visualized to the user in a push mode. An example of this can be found in the *Scopes* system (Rahlff 2004). Here in addition to *location* the other cardinal dimensions are: *time*, *people*, *objects*, *documents*, *tasks*, and *roles*. The purpose of such a system is to make the reasoning of the system obvious and correctable to the user. This model also enables the user to reverse the flow into a pull model, where the context assumed by the system may be overridden by a push-operation along one of the context dimensions.



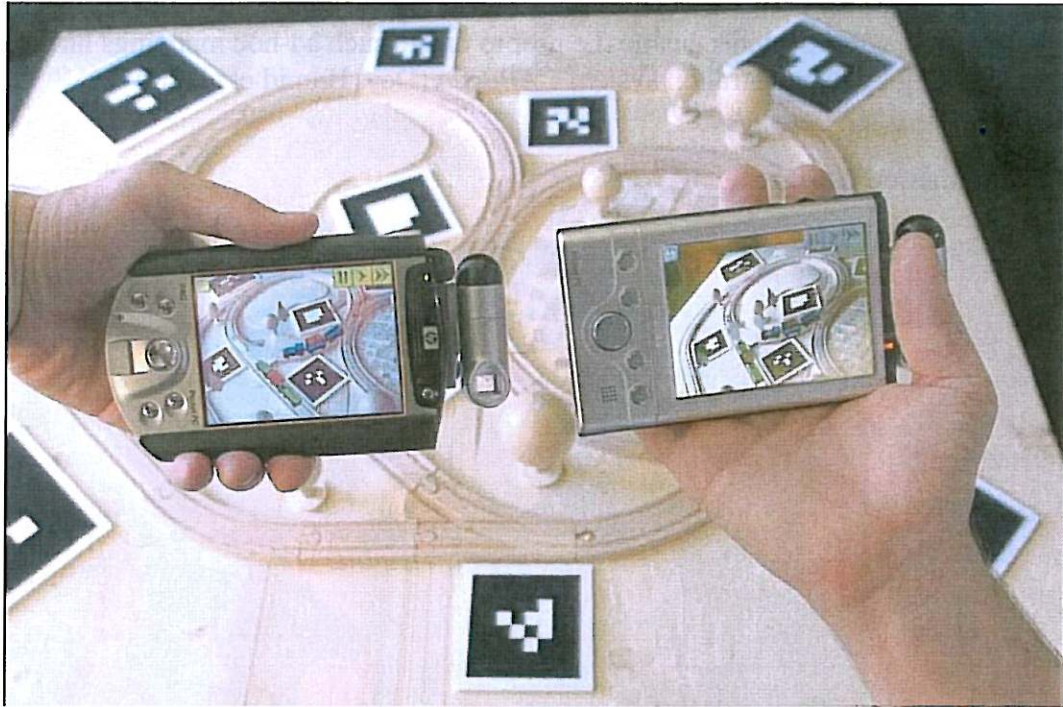
Abstracted Scopes UI from Rahlff

As all useful connections between sensed context and desired system response cannot be premeditated, some systems enable the user to create such ad-hoc mappings himself as in the programming by demonstration system *CAPpella* (Dey, Hamid et al. 2004).

4.2 Augmented context



Augmented context is when the current context is used as a multidimensional index for retrieving additional information, such as the tourist information triggered from GPS-context in (Abowd, Atkeson et al. 1997). These systems can be anything from very slow-coupling systems such as visual codes retrieving MMS as in *CybStickers* (Rahlff 2005) to direct readout of RFID markers as (NFC 2006) and to fast paced augmented reality applications where e.g. a camera image is continually updated with additional visual markers making the image a “magic eye” or “visual portal” like the *Invisible Train Demo* created with ETH’s *ARToolkit* (Wagner, Pintaric et al. 2005).



Invisible Train Demo from (Wagner, Pintaric et al. 2005)

4.3 Contextual services

Contextual communication is when the changed context facilitates communication, such as Bluetooth communication by proximity, or being notified of buddies present within an area.

4.4 Contextual resource usage

On the opposite scale are attempts to generate interfaces that span several devices and change according to context or attempt to keep a certain QoS as context changes. Some systems compensate for limited focus when a user moves by providing a fish-eye view display of e.g. web pages (Zhang 2007).



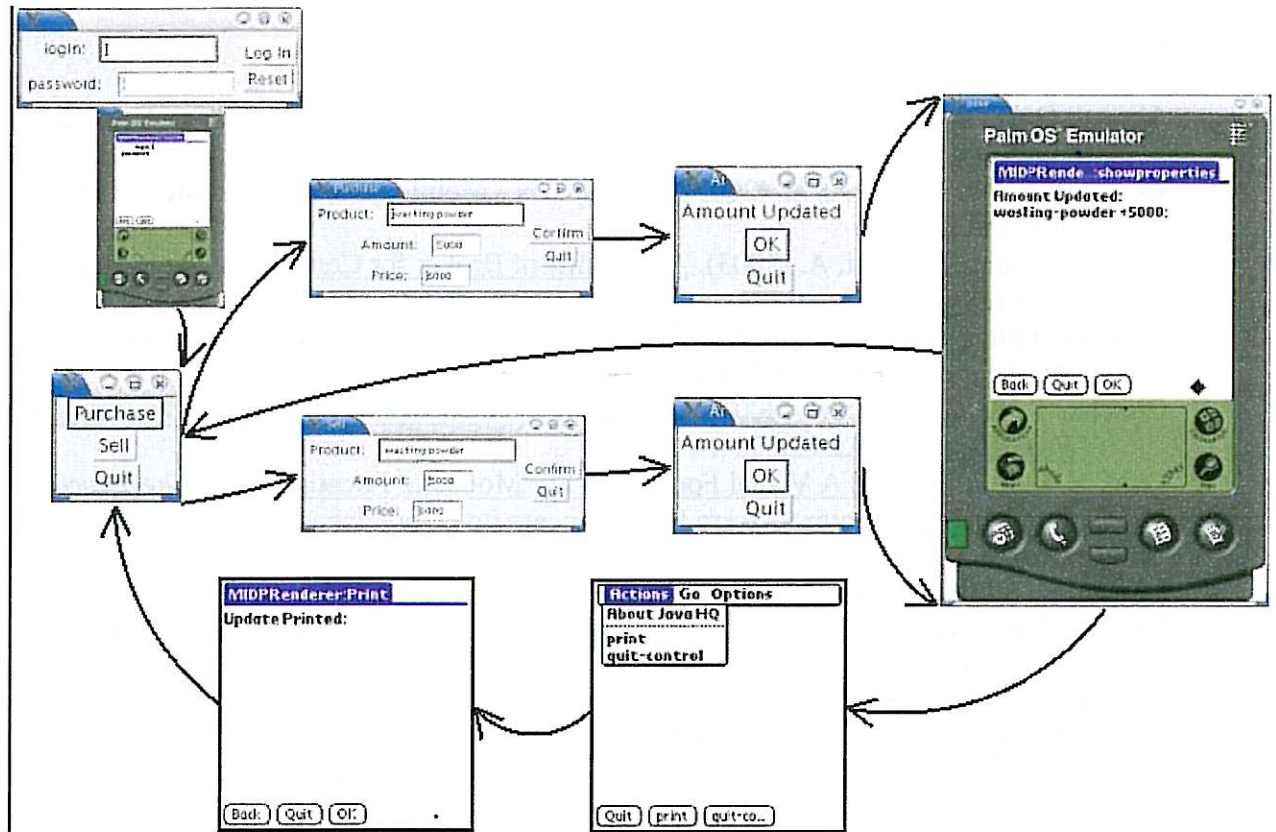
Without fisheye



With fisheye

Web content adaptation for mobile user from (Zhang 2007).

Another example of automatic UI reconfiguration can be found in (Clerckx, Luyten et al. 2004), it demands however, that the context of use is stable once the devices have reached a triggered configuration.



Automatically rendered screens (Clerckx, Luyten et al. 2004)

5 Conclusion

This survey has shown that there are different usage perspectives for utilizing context information in a mobile information system. The purpose of the system influences how this changing context may be used in the user interface or the underlying system.

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Relevant conferences

- **CONTEXT '07** , *The Sixth International and Interdisciplinary Conference on Modeling and Using Context*, <http://context-07.ruc.dk/> . Oldest conference on context. Interdisciplinary approach.
- **CoMOREa ' 07** *4th IEEE Workshop on Context Modeling and Reasoning*, <http://nexus.informatik.uni-stuttgart.de/COMOREA/2007/CallForPapers07.html>