Modeling Context Constraints

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Berlin, September 7th, 2006
Outline

Introduction
Context Model
Transformation of Context Dimensions
Service Scope Model
Service Scope Representation
Example
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Need for Defining Context Constraints: Service Roaming

Services often have limited scope

Users (especially mobile users) change their contexts frequently

Services are valid for a certain user if user context is within service scope

Whenever the context leaves the scope service roaming is needed
Context

Defined by values of n context dimensions

Represented by an n-tuple

In this example: 3 dimensions

C=(latitude, longitude, time)

Certain value for each context dimension

Single point in context hyperspace

Current context values of an entity (a user)
## Context Hyperspace

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Cartesian n-dimensional space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions defined for</td>
<td>([-\infty; \infty])</td>
</tr>
<tr>
<td>Dimensions defined on</td>
<td>(\mathbb{R})</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Context attributes</th>
<th>Often limited range (e.g. longitude ([-180;180]))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not always defined on (\mathbb{R}) (e.g. room numbers)</td>
</tr>
<tr>
<td></td>
<td>Not always numbered (e.g. weather: cloudy)</td>
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<tr>
<td></td>
<td>Not always distinct (e.g. language capabilities: DE, EN)</td>
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Scales of Measurement, Scale of Representation

**Scales of measurement**
- **Nominal**
  Equal or unequal (e.g. male, female)
- **Ordinal**
  Nominal + order of values (e.g. room numbers)
- **Interval**
  Ordinal + definite difference (e.g. temperature)
- **Proportional / rational**
  Interval + natural zero point (e.g. length)

**Scale of representation**
- Always proportional scale (because defined on \( \mathbb{R} \))
Transformation

Context attributes
For each context attribute $c_i$ there has to be a transformation into the representation attribute $d_i$

$$\forall c_i : \exists f(c_i) \rightarrow d_i ; d_i \in R$$

This transformation is injective
(For each input value there is a distinct output value)

Context semantics
Context may consist of more than name/value pairs

Semantics are separated from values (semantic layer)

Semantic layer
Contains scale of origin, relationships between context dimensions, ... (Not necessary for service roaming!)
## Context Representation

<table>
<thead>
<tr>
<th>Operations</th>
<th>Proportional scale allows many operations (Order, difference, ratio, ...)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Only check for equality is needed for service roaming =&gt; Only this is allowed on the context representation per default</td>
</tr>
<tr>
<td></td>
<td>All other operations are supported only if allowed by the semantic layer</td>
</tr>
<tr>
<td>Integrity</td>
<td>$\text{op}(f(c_i)) = f(\text{op}(c_i))$</td>
</tr>
<tr>
<td>Reverse transformation</td>
<td>Leads to initial context value</td>
</tr>
</tbody>
</table>
Service Scope Representation

Service scope: n-dimensional polytope
(Assumption of linearity for simplification)

Two (popular) ways of representation:

- Boundary representation
  Each n-dimensional object is recursively described by its (n-1)-dimensional boundaries

- Constraint representation
  Systems of linear inequations, each of them defining a half-hyperspace
## Comparison of Representations

<table>
<thead>
<tr>
<th>Representation</th>
<th>Characteristics</th>
</tr>
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<tbody>
<tr>
<td><strong>Boundary</strong></td>
<td>Very popular in Solid Modeling</td>
</tr>
<tr>
<td></td>
<td>Used in GIS for representation of 2D/3D objects</td>
</tr>
<tr>
<td></td>
<td>Very verbose for n-dimensional objects (for large n’s)</td>
</tr>
<tr>
<td></td>
<td>$b_n \geq \prod_{i=1}^{n} i + 1$ (b$_n$: number of bounding objects)</td>
</tr>
<tr>
<td><strong>Constraint</strong></td>
<td>Only capable to describe convex objects</td>
</tr>
<tr>
<td></td>
<td>Less computation for ‘INCLUDES‘ operator</td>
</tr>
<tr>
<td></td>
<td>Easier to convert boundary representation to constraint representation than other way round</td>
</tr>
</tbody>
</table>
**Decision: Constraint Representation**

<table>
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<tr>
<th>Reasons</th>
<th>Verbosity of boundary representation is major criteria</th>
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<tr>
<td></td>
<td>Many restrictions are already initially in constraint representation (e.g. time $\geq 8:00$)</td>
</tr>
<tr>
<td></td>
<td>Only few restrictions are initially in boundary representation (e.g. spatial restrictions by polygons)</td>
</tr>
</tbody>
</table>

| Non-convex scopes | Each non-convex polytope can be decomposed into a set of convex polytopes. |
Example

Constraints:

Time: between 8:00 and 21:00

Space: Within the following polygon
Spatial Dimensions

1. \( x_1 = -x_2 + 1.4 \)
2. \( x_1 = -0.125x_2 + 0.6 \)
3. \( x_1 = 0.4x_2 - 0.9 \)
4. \( x_1 = -0.75x_2 + 3.6 \)
5. \( x_1 = 0.16x_2 + 1 \)
6. \( x_1 = -0.4x_2 + 2 \)
7. \( x_1 = 0.6x_2 + 1 \)

\[
\begin{align*}
    x_1 &\geq -x_2 + 1.4 \quad \iff -x_1 - x_2 + 1.4 \leq 0 \quad (1) \\
    x_1 &\geq -0.125x_2 + 0.6 \quad \iff -x_1 - 0.125x_2 + 0.6 \leq 0 \quad (2) \\
    x_1 &\geq 0.4x_2 - 0.9 \quad \iff -x_1 + 0.4x_2 - 0.9 \leq 0 \quad (3) \\
    x_1 &\leq -0.75x_2 + 3.6 \quad \iff x_1 + 0.75x_2 - 3.6 \leq 0 \quad (4) \\
    x_1 &\leq -0.4x_2 + 2 \quad \iff x_1 - 0.4x_2 + 2 \leq 0 \quad (5) \\
    x_1 &\geq 0.4x_2 - 0.9 \quad \iff -x_1 + 0.4x_2 - 0.9 \geq 0 \quad (6)
\end{align*}
\]
Time Dimension

Restriction
Daily from 8:00 to 21:00

Transformation daytime
\[ d_{\text{time}} = f(c_{\text{time}}) = \text{hours}(c_{\text{time}}) \times 60 + \text{minutes}(c_{\text{time}}) \]
\[ c_{\text{time}} = 8:00 \Rightarrow d_{\text{time}} = 480 \]
\[ c_{\text{time}} = 21:00 \Rightarrow d_{\text{time}} = 1260 \]

Constraints
\[ x_3 \geq 480 \quad \Leftrightarrow \quad -x_3 + 480 \leq 0 \]
\[ x_3 \leq 1260 \quad \Leftrightarrow \quad x_3 - 1260 \leq 0 \]
### Matrix Representation of Service Scope

**Spatial Restrictions**

\[
\begin{align*}
-x_1 - x_2 + 1,4 & \leq 0 \\
-x_1 - 0,125x_2 + 0,6 & \leq 0 \\
-x_1 + 0,4x_2 - 0,9 & \leq 0 \\
x_1 + 0,4x_2 - 2 & \leq 0 \\
x_1 - 0,59x_2 - 1 & \leq 0 \\
-x_1 + 0,4x_2 - 0,9 & \leq 0 \\
x_1 + 0,75x_2 - 3,6 & \leq 0 \\
x_1 - 0,16x_2 - 1 & \leq 0 \\
x_1 - 0,4x_2 + 2 & \leq 0 \\
\end{align*}
\]

**Time Restriction**

\[
\begin{align*}
-x_3 + 480 & \leq 0 \\
x_3 - 1260 & \leq 0
\end{align*}
\]

**Matrices**

\[
\begin{pmatrix}
-1 & -1 & 0 & 1,4 \\
-1 & -0,125 & 0 & 0,6 \\
-1 & 0,4 & 0 & -0,9 \\
1 & 0,4 & 0 & -2 \\
1 & -0,59 & 0 & -1 \\
0 & 0 & -1 & 480 \\
0 & 0 & 1 & -1260
\end{pmatrix}
\]

\[
\begin{pmatrix}
-1 & 0,4 & 0 & -0,9 \\
1 & 0,75 & 0 & -3,6 \\
1 & -0,16 & 0 & -1 \\
-1 & -0,4 & 0 & 2 \\
0 & 0 & -1 & 480 \\
0 & 0 & 1 & -1260
\end{pmatrix}
\]
Is Context Within Service Scope?

<table>
<thead>
<tr>
<th>Definition</th>
<th>Context is within service scope if context is element of the solution set of one of the matrices.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Context (2,9; 1,2; 555) (lat = 2,9; long = 1,2; time = 9:15)</td>
</tr>
<tr>
<td>Result</td>
<td>$(2,9; 1,2; 555) \in \mathbb{M}_2$</td>
</tr>
<tr>
<td></td>
<td>$\Rightarrow$ Context is within service scope and service is valid!</td>
</tr>
</tbody>
</table>
Conclusion

Context model

- Different context models exist in literature
- Service roaming only needs context data
- Context semantics are separated in semantic layer
- Context data + semantic layer + transformation functions should maintain all information provided by existing context models

Scope representation

- Proposed representation is absolutely generic
- Linear scopes should be sufficient
- Constraint representation is preferable
Thanks for your attention!

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