Modeling and Coordinating Social Interactions in Pervasive Environments

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Outlines

- Background
- Motivating Scenario
- Research Challenges
- Literature Review
- Approaches
  - Role based modeling
  - Fuzzy inference for task quantification
- System Design and Implementation
- Conclusions
Background

Pervasive Computing (early 1990s)

- Envisions environments where people are assisted in their everyday tasks by technologies – being invisible yet significantly helpful

Context-awareness (in 1994)

- Context – any information that characterize the situation of an entity
- Context-awareness – ability to use context information to provide services
Pervasive Social Computing

- Aims to take advantage of human social relationships to enable the fulfillment of users’ task on the move
- Computer mediated means of social interaction by recognizing social context...

Social Interaction

- Sequence of social action between individuals by considering their relationships
- Social Context – represents the social relationships among the actors (human, agents, software systems)
Motivating Scenario

Smart Home → Smart Phone/PDA → Smart Office

Social Context

Physical context

Market

Home

Workplace
Research Challenges

- **Modeling Social Interactions**
  - Requires a representation of *constructed relationships*, norms, obligations, and constraints (domain-centric model)
  - Can not be simply acquired from physical and virtual sensors
  - An actor might operate in different domains simultaneously – he/she might have its *own coordinated view* of social contexts (player-centric model)

- **Research Question**
  - How to model social interactions from both *domain-* and *player-* perspectives
Research Challenges (cont..)

- Coordinating Social Interactions
  - The involvement of an individual in *multiple concurrent interactions* may incur conflict
  - An actor might have *own preference* for each interaction also he/she might want the application to *carry out* certain interactions on behalf

- Research Question
  - How to infer the *overall importance* of each interaction
Architecture of Context-aware System

Layer 1: Sensors
(Physical and Virtual sensors)

Layer 2: Physical Context Management
(Middleware Layer)
- Models
- Interpreters
- Aggregators
- Repositories
... 

Layer 3: Context-aware Applications
(Functional Implementation, Coordination and Adaptation Logic)

The constructed relationships between actors, their interaction constraints, and the coordination logic are not modeled explicitly.
Social Interaction Modeling

- Multi-agent system
  - Kalenka and Jennings, 2002 – multi-furious social interaction attitudes ranking from self interested to the purely altruistic to enhance agent interactions
  - Cabri et al., 2003 – propose framework relies on the concept of role for developing agent based applications but it does not consider the user’s perspective of interaction modeling with the issue of playing multiple roles

Context modeling approaches

- Bettini et al., 2010 reviewed – Graphical approach, Object oriented, mark-up scheme, logic-based, and ontological models
  - Those approaches were developed to model physical context (e.g., representing context facts and relationships between context facts) and they provide limited support for modeling social context (i.e., interaction-oriented context)
Social Applications

<table>
<thead>
<tr>
<th>Area</th>
<th>Year</th>
<th>Authors</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Digital Assistant</td>
<td>2009</td>
<td>Bosse et al.</td>
<td>A personal assistant agent to monitor the user’s state and task execution</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>Helmy et al.</td>
<td>A personal information manager to support speech recognition and calendar scheduling</td>
</tr>
<tr>
<td>Social mobile application</td>
<td>2005</td>
<td>Smith</td>
<td>RENO – an application for locating friends by calculating the device's approximate location</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>Erfurth et al.</td>
<td>An application to find human partners in close proximity with same interest</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>Pernek and Hummel</td>
<td>SocioNet – a context-aware rule based system for mobile devices to find best matching persons in proximity</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>Hung et al.</td>
<td>A system social network agents for managing social contacts over the web</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>Stoica and Auouris</td>
<td>A context-aware application to support personalized interaction across multiple augmented spaces</td>
</tr>
</tbody>
</table>

None of these facilitate personalized social interactions with coordination functionality and management
### Modeling Social Interactions

#### Role based approach

- Design considerations: *Domain-* and *Player-*centric perspectives
- Concepts to notational representation

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Notational Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social role</td>
<td>Social Role</td>
</tr>
<tr>
<td>User/Human</td>
<td>Actor/Player</td>
</tr>
<tr>
<td>Norms (behaviour patterns)</td>
<td>Contract/ Association</td>
</tr>
<tr>
<td>Obligations</td>
<td>Interaction clause</td>
</tr>
<tr>
<td>Social relationship</td>
<td>Conversation clause</td>
</tr>
<tr>
<td>Human decision making role</td>
<td>Obligations</td>
</tr>
<tr>
<td>User and socially-aware application</td>
<td>Coordinator role</td>
</tr>
<tr>
<td>User’s physical, environmental and geographical information</td>
<td>Player of coordinator role</td>
</tr>
<tr>
<td>User’s preference and expected behaviour</td>
<td>Physical context</td>
</tr>
<tr>
<td></td>
<td>Context rules</td>
</tr>
</tbody>
</table>

For both Domain- and Player-centric

Player-centric

16th IEEE International Conference on Engineering Complex Computer Systems (ICECCS) 2011, Las Vegas, USA
Domain-centric model

It captures interactions associated with a particular domain/environment (e.g., home, work, shopping mall)
Domain-centric model

- **Contract** – an association between two roles
  - *Interaction clause* – defines possible functional interactions between two roles/direction and types of requests and notifications
  - *Conversational clause* – defines acceptable sequences of interactions
  - *Obligation clause* – defines time constraints of interactions

<table>
<thead>
<tr>
<th>Contract ID</th>
<th>C1: ElderlyMother_Son</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parties:</td>
<td>A: Mother; B: Son;</td>
</tr>
<tr>
<td>Interaction Clauses</td>
<td></td>
</tr>
<tr>
<td>i1:</td>
<td>{contactMother, BtoA, motherResponse}</td>
</tr>
<tr>
<td>i2:</td>
<td>{situationAsking, BtoA, situationAnswering}</td>
</tr>
<tr>
<td>i3:</td>
<td>{contactSon, AtoB, sonResponse}</td>
</tr>
<tr>
<td>i4:</td>
<td>{askToReturnHome, AtoB, sonResponse}</td>
</tr>
<tr>
<td>i5:</td>
<td>{comingBackHome, BtoA}</td>
</tr>
<tr>
<td>Conversation Clauses</td>
<td></td>
</tr>
<tr>
<td>c1:</td>
<td>{i3 precedes i4};</td>
</tr>
<tr>
<td>Obligations</td>
<td></td>
</tr>
<tr>
<td>o1:</td>
<td>{i3, Timer, duration, &lt;, 30, seconds};</td>
</tr>
<tr>
<td>o2:</td>
<td>{i2, Timer, duration, &lt;, 40, seconds};</td>
</tr>
<tr>
<td>o3:</td>
<td>{i2, Timer, periodic, =, 30, minutes};</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Contract ID</th>
<th>C2: Relative_EmergencyService</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parties:</td>
<td>C: EmergencyService; B: Son</td>
</tr>
<tr>
<td>Interaction Clauses</td>
<td></td>
</tr>
<tr>
<td>i6:</td>
<td>{callAmbulance, BtoC, askAddress}</td>
</tr>
<tr>
<td>i7:</td>
<td>{informAddress, BtoC, sendAmbulance}</td>
</tr>
<tr>
<td>i8:</td>
<td>{notifyPickUp, CtoB}</td>
</tr>
<tr>
<td>i9:</td>
<td>{notifyHospitalAddress, CtoB}</td>
</tr>
<tr>
<td>Conversation Clauses</td>
<td></td>
</tr>
<tr>
<td>c2:</td>
<td>{i7 precedes i8};</td>
</tr>
<tr>
<td>Obligations</td>
<td></td>
</tr>
<tr>
<td>o4:</td>
<td>{c2, Timer, duration, &lt;, 10, mins};</td>
</tr>
</tbody>
</table>
Meta model for Domain-centric model

- Organizer Role
- Contract
- Social Role
- Player
- DSCM

1. Organizer Role is managed by Organizer Player.
2. DSCM is part of Organizer Role.
3. DSCM is defined by Contract.
4. Social Role is part of DSCM.
5. Social Role is bound to Player.
6. Contract forms DSCM.
7. Organizer Role plays/bound to DSCM.
8. Player plays/bound to Social Role.
Modeling Social Interactions (Cont..)

- **Player-centric model**
  - Aggregates all potential interactions of an individual (with *personal preferences*) according to his/her different roles to facilitate *coordination* functionality
  - Coordinator role – played by a socially-aware application to coordinate requested tasks

![Diagram of John's social context]
Modeling Social Interactions (Cont..)

- **Player-centric model**
  - Role-centric contract – aggregation of all the contracts associated with a particular role in a domain centric model
  - Context rules – specify user’s personal preferences and adaptive behavior

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<table>
<thead>
<tr>
<th>Contract ID</th>
<th>C7: SonRole-centricContract;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parties</td>
<td>A: Coordinator; B: Son;</td>
</tr>
<tr>
<td>Physical Context Fact Providers</td>
<td>B_SituationDetector;</td>
</tr>
<tr>
<td>Social Context Fact Providers</td>
<td>sConflict;</td>
</tr>
<tr>
<td>Interaction Clauses</td>
<td>All interaction clauses in table I: i1 to i9</td>
</tr>
<tr>
<td>Conversation Clauses</td>
<td>All clauses in table I: c1 and c2</td>
</tr>
<tr>
<td>Obligations</td>
<td>All clauses in table I: o1 to o4</td>
</tr>
</tbody>
</table>

**Context rules**

- r1: //specifying preference-will be used in task evaluation
  - when i2.situationAnswering received
  - if situationAnswering=NotFeelingGood && sConflict=TRUE
  - do Set P(comingBackHome) = 0.6 //set personal preference

- r2: initiateEmergencyProcedure: //adaptive behaviour
  - when i2.situationAnswering or i4.askToReturnHome received
  - if B_SituationDetector=MEETING||SEMINAR && situationAnswering=HEART-ATTACK
  - do A.callAmbulance
Metal model for Player-centric model

- **Actor** plays/bound to **Coordinator Role**
- **Organizer Role** owned by **Actor** and managed by **PSCM**
- **Coordination Role** coordinates interactions
- **Persona** plays/bound to **Social Role**
- **Social Role** characterizes **Role-centric Contract**
- **PSCM** part of **Role-centric Contract**
Coordinating Social Interactions

- **Fuzzy inference for task quantification**
  - *Priority* – importance of a task from *requester’s* point of view
  - *Preference* – importance of a task from *receiver’s* point of view
  - *Consequence* – loss (if reject the task request) and gain (if accept)
  - *Overall importance* – importance of a task based on the above three predicate values

![Membership function value](image)

- Membership function value
- Membership function value

- Priority (3)
- Preference (3)
- Consequence (3)

- Task quantification
- (membership)
- 27 rules
- Overall importance (5)

System task quantification: 3 inputs, 1 outputs, 27 rules
Coordinating Social Interactions

- Fuzzy inference for task quantification
- Specify 27 fuzzy control rules from social psychology and human behavior literature study

<table>
<thead>
<tr>
<th>Fuzzy control rules when consequences = low</th>
<th>Preference low</th>
<th>Preference medium</th>
<th>Preference high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority low</td>
<td>Not important</td>
<td>Not important</td>
<td>Not important</td>
</tr>
<tr>
<td>Priority medium</td>
<td>Not important</td>
<td>Less important</td>
<td>Less important</td>
</tr>
<tr>
<td>Priority high</td>
<td>Less important</td>
<td>Less important</td>
<td>Moderately imp</td>
</tr>
</tbody>
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<th>Preference high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority low</td>
<td>Moderately imp</td>
<td>Moderately imp</td>
<td>Very important</td>
</tr>
<tr>
<td>Priority medium</td>
<td>Moderate imp</td>
<td>Very important</td>
<td>Very much imp</td>
</tr>
<tr>
<td>Priority high</td>
<td>Very important</td>
<td>Very much imp</td>
<td>Very much imp</td>
</tr>
</tbody>
</table>
System Design and Implementation

- Extending conventional Context-aware System architecture
- Role Oriented Adaptive Design (ROAD)* framework
  - Used to design self-adaptive software systems
  - Separates the management structure from the functional structure


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Tool support and Deployment

Modeling Tool

XML representation of DSCM/PSCM

Middleware

Modeling Tool

Design-time

Design Social Context Model (ROADdesigner)

Run-time

Create Classes of Social Context (ROADfactory)

Run-time Monitoring/Adaptation (Web Services)

Generate XML Document (Eclipse EMF/GEF)

verify

Model Schema

XSD

Interaction terms are exposed as Web service methods

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Prototype Implementation

Applications

Middleware

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Trust and Validation

- **Trust** through *Why* expiation – by showing users the *three topmost* fuzzy rules that contribute most in the inference process.

```
1. If (Priority is medium) and (Preference is medium) and (Consequences is medium) then (overall_importance is moderate)
2. If (Priority is high) and (Preference is medium) and (Consequences is medium) then (overall_importance is moderate)
3. If (Priority is medium) and (Preference is low) and (Consequences is medium) then (overall_importance is less_important)
```

- Intuitive *validation* (revisiting the scenario)

<table>
<thead>
<tr>
<th>#</th>
<th>Task</th>
<th>Priority</th>
<th>Preference</th>
<th>Consequence</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>comingBackHome(s₁)</td>
<td>0.8</td>
<td>0.8</td>
<td>0.85</td>
<td>0.7</td>
</tr>
<tr>
<td>2</td>
<td>comingBackHome(s₂)</td>
<td>0.9</td>
<td>0.8</td>
<td>0.4</td>
<td>0.58</td>
</tr>
<tr>
<td>3</td>
<td>attendMeeting</td>
<td>0.9</td>
<td>0.7</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1.0</td>
<td>0.7</td>
<td>0.5</td>
<td>0.6</td>
</tr>
</tbody>
</table>

\[ s₁: \text{Mother.situation=NotFeelingGood}, s₂: \text{Mother.situation=Well} \]
Conclusions

- Present an approach to facilitate social interactions
- Explore the concept of social context to represent social relationships
  - Model it from both domain- and player-perspective
- Propose an approach to coordinate multiple concurrent interactions
  - Fuzzy inference technique for task quantification
- Have developed a modeling tool and middleware
- Demonstrate its applicability by developing mobile applications
Thank you!

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