A Context-Aware Method for Spontaneous Clustering of Dynamic Wireless Sensor Nodes

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Self-organization

- Self-organization in wireless ad-hoc and sensor networks
  - From an initially unstructured network, build a structure in a distributed manner
  - Decisions are based on networking characteristics (e.g. link quality), node capabilities (e.g. amount of storage), probabilistic...
  - Purpose: efficient networking, data storage, querying
  - Operation: MAC, routing, transport, service discovery
  - Examples of structures: P2P overlay networks (e.g. DHT), hierarchical (e.g. spanning tree), hybrid (e.g. hierarchical rings, local hierarchies – clusters)
Self-organization

- Wireless ad-hoc and sensor networks – self-organization at the **application** layer
  - Rely on operational networking protocols
  - Build a structure in a distributed manner, based on **context information** (e.g. moving together) – virtual representation of the structures present in the real world
  - Purpose: provide a service for the application
  - Challenge: how to build stable clusters when the context information changes in time?
Application: transport and logistics
Application: Body Area Networks

- Wearable computing – nodes placed on the same person
- Clustering of nodes based on movement of people
  - Automatic identification of the sensors worn
  - Contribute to the activity monitoring and recognition
  - Can form a secure network
Phases of self-organization

1. Context-recognition algorithm
2. Communication of context information
   • Context is permanently evaluated and communicated
3. Algorithm of self-organization based on context information
   • Takes into account the variability of context information
Context-recognition algorithm – moving together

Tilt switches
- Binary information over the status of the device (moving/not moving)
- We use the number of contacts per time unit

Accelerometers
- Measures the acceleration on three axis
- We use the magnitude of the acceleration vector:

\[ \| \mathbf{a} \| = \sqrt{a_x^2 + a_y^2 + a_z^2} \]
Context-recognition algorithm – moving together

- Sampling of movement sensors
- Communication of movement data
- Computation of the correlation coefficient

Corr = 0.896
Context-recognition algorithm – moving together

Experimental Settings
Context-recognition algorithm – moving together

Accelerometers moving together
Context-recognition algorithm – moving together

Accelerometers moving separately
Context-recognition algorithm – moving together

Accuracy

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Setting</th>
<th>Movement type</th>
<th>Mean</th>
<th>Stdev</th>
<th>Accuracy [%]</th>
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<tbody>
<tr>
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• Body Area Networks - coherence function [2]
  – A number in [0,1] that indicates whether two signals are correlated at a particular frequency
  – Accuracy 70% - 87.5%

Algorithm of self-organization - Tandem

- Assumption: each node runs a **context recognition algorithm** for all the neighbours
  - Provides a number on a scale, the confidence value
    - Coherence function \([0:1]\)
    - Correlation coefficient \([-1:1]\)
  - Permanently evaluates the context
  - The confidence value changes in time
  - The algorithm has a certain accuracy
  - False negatives and false positives for the perceived shared-context
Algorithm of self-organization - Tandem

Follows the idea of a greedy algorithm, with the characteristics:

1. Incorporate dynamics
   - Merging and splitting of clusters depending on:
     - Topology changes
     - Context changes

2. Stability
   - The periodic re-evaluation of shared context may lead to unstable clusters
     - Analyze the confidence value for a longer period of time
     - Tradeoff between stability and delay
Algorithm of self-organization - Tandem

Context-aware self-organization

- Context-aware self-organization – a variant of the classical clustering, with different applications and requirements
  - Virtual representation of structures present in the real world
  - **Passive** approach, does not act, but only tries to understand
- **Active** self-organization: wireless sensors and actuator networks
  - **Build and control** the structures of the real world
Collaborative unmanned vehicles

- Equip vehicles with wireless sensor and actuator nodes.
- Make the vehicles coordinate their motion, e.g. follow a leader and thus maintain a formation.
FollowMe!

FollowMe!

- For a presentation and demonstration video, please visit:
  http://www.youtube.com/watch?v=ZzWYO5dbo1M