The Future of Cities and Urban Environments

- A very dense digital ecosystem of interconnected individuals: sensors, actuators and citizens.

- A socio-technical ecosystem that delivers advanced urban services through SAC capabilities.
- Complementary sensing, computing and actuating capabilities.

- Cooperation towards the achievement of urban-level goals.

<table>
<thead>
<tr>
<th>SAC Capabilities of Individuals</th>
<th>ICT Devices</th>
<th>Humans</th>
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<tbody>
<tr>
<td><strong>Sensing</strong></td>
<td>- RFID tags</td>
<td>- 5 human senses</td>
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<td></td>
<td>- Mobile phones</td>
<td>- Social networks</td>
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<td>- NFC tags</td>
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<td></td>
<td>- Wearable devices</td>
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<td></td>
<td>- Environmental sensors</td>
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<tr>
<td><strong>Computing</strong></td>
<td>- Data analysis</td>
<td>- Human computation</td>
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<td>- Data processing</td>
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<td>- Pattern recognition</td>
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<td>- Machine learning</td>
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<td><strong>Actuating</strong></td>
<td>- Traffic lights</td>
<td>- Actions</td>
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<td>- Road signs</td>
<td>- Activities</td>
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<td>- Public displays</td>
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Loop of the SAC capabilities for coherent collective behavior.

Plan for collective actions for adaptively steering the dynamics of the city.
Urban Superorganism

- Bio-inspired mechanisms
- Self-organizing pattern modules
Case study: Intelligent Transportation System

- **Collective sensing**
  - Humans sharing traffic-related events
  - ICT devices monitoring traffic in real-time

- **Collective awareness**
  - Traffic congestion inferred by road characteristics context
  - ITS endowed with situation aware modules

- **Collective actions**
  - Modelling current traffic conditions dynamically
  - Recommending re-routings, intermodal routes or viability changes
Challenges for Superorganism architecture

- High degree of Awareness
- Heterogeneity and Interoperability
- Dynamic re-Configurability
- Interconnection
- Dynamic selection
- Mixing Bottom-up and Top-down design
An architectural proposal

- Two tier Middleware
- On individuals, enabling Superorganism features
- Computational Engines in a Cloud Environment
Middleware on individuals

- Low layer API to abstract SAC capabilities
- Awareness module
- Self optimizing and reconfiguring module
- Interconnection module
Awareness module
Middleware on computational engines

- Dynamic injection of pervasive services.
- Sensing specific aspects.
- Reacting to specific situations in a given context.
- Actuating urban superorganism to optimize and steer.
Experimental evaluation - Modularity

Vehicle Classifier - Precision

Vehicle Classifier - Recall

Automata-Driven Always-On
Experimental evaluation - Scalability

Heap Memory Usage

Throughput
Conclusions and Future Work

- Collaborative and Collective Behavior resulting in Urban Intelligence
- Investigating many research challenges
- Developing suitable middleware infrastructures
- Implementing early prototypes
- Establishing a Unified Approach
Thanks!

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