Complexity, governance and the smart city

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- Materials and methods
  - Agent-based modelling
  - The formalization and modelling of relations
  - The acquisition of inputs and the formalization of languages
- Discussion: modelling knowledge
- Conclusion

Introduction

- Cities raise interest around their inherent, genetic concept of **environmental complexity**
  - An element of **richness**, opportunities and raison d'être
- Models of **distributed governance**, rather than top-down centralized government
- Smart-city organization goes **beyond diffused infrastructuring** *per se*
  - Managing this complexity, through **multi-agent knowledge**
  - Linking times, spaces, agents through geophysical relationships but also emotional, creative, **informal trusts**
  - Building **adequate architectures** homotetically related to such complexity
- Recent **ontology-based approach** to support the understanding and modellization of this multimensional cognitive assortment

Conceptual background

- 'Smartedness' brings us back to the '**wired city**' of the 1980s.
  - Envisioned scenarios for the **improvement of public services** and (particularly communication) infrastructures, to increase the wellbeing of citizens.
- Then the Internet: small or large realities could indifferently rise to the international spotlight through **simple computational agents**
- Explosion of **wireless** connections in early 2000s.
  - In **developing Countries** they made new informative independence perspectives for agents, boosting new socializing, aggregative attitudes
- In the 21st century, new inter-agent communication:
  - the extraordinary diffusion of **social networks** and the perspectives of **IoT**

- Smart city can enhance **urban sustainability** and livability.
- **Knowledge** is an essential but also extremely dynamic factor

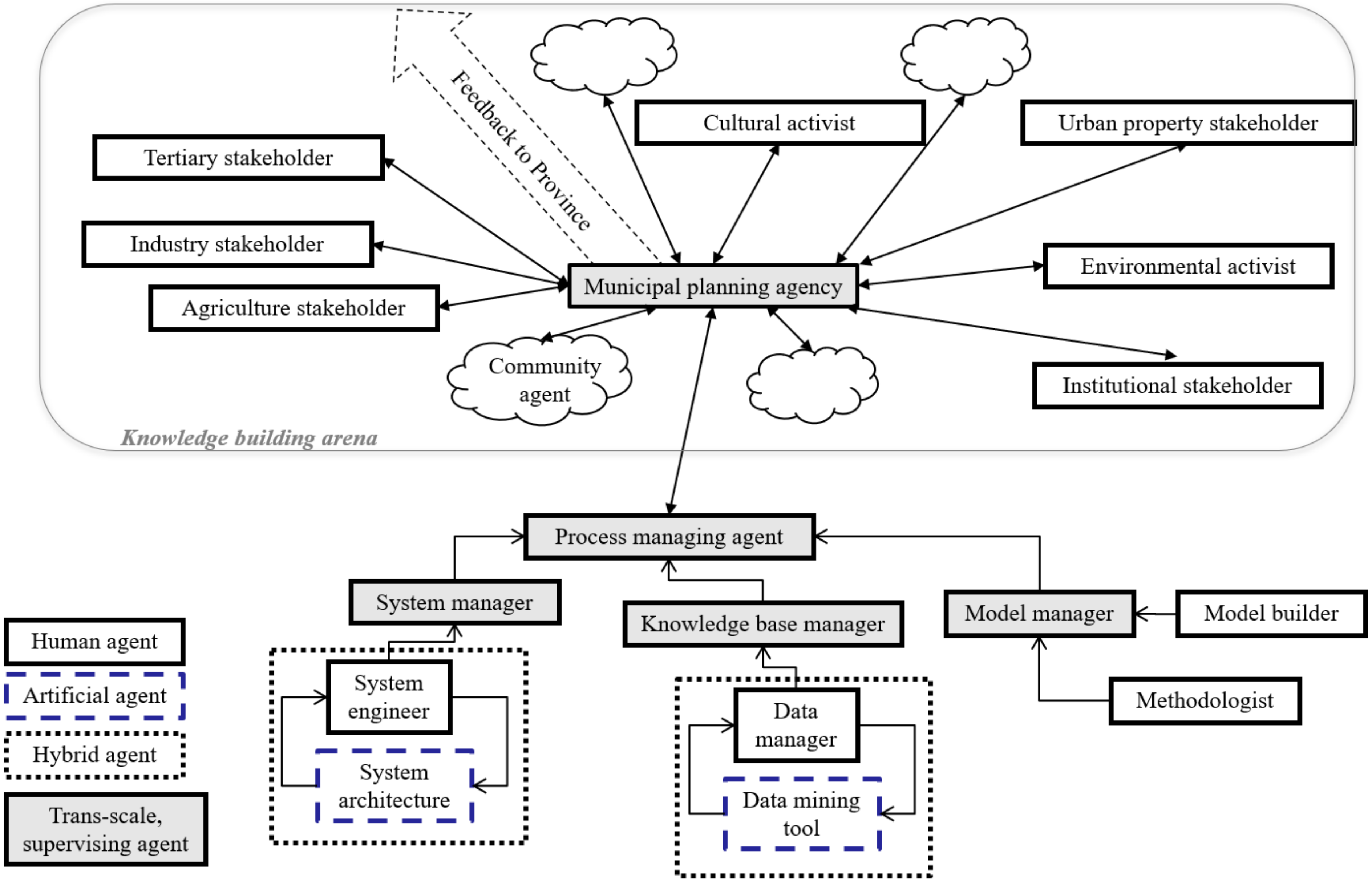
- In urban planning, for example, the question is often of building bottom-up, **inclusive future development scenarios**
- City is an open and **evolutionary system** with in-out information flows and temporal dynamics
  - Need for **agents‘ knowledge, exchanged** in arenas of cognitive interaction
  - **Architectures** able to manage cognitive connections dynamically variable
- This qualitative leap is still difficult to achieve

Agent-based modelling

- A multi-agent system model (MAS) can contain human, but also artificial, automatic, or a **hybrid mix of agents** of various kinds and with various behaviours at the same time.
  - significantly **reproducing the richness** implicit in environment complexity, while maintaining the necessary **knowledge for decision-making** processes.
- Moreover, MAS approach contains **hierarchical articulation** of tasks and mutual behavior between agents.
  - An example: MAS-based **supply chains**, in which agents‘ tasks along the distribution chain vary from simple routine to coordination and supervision
- MAS are inherently **able of adapting** to complex organizations
  - supporting **multi-scale governance**

- Agents can be **natural actors** of environmental life (human agents, animal agents, etc.), or **artificial entities** of cognitively high or low levels (sensors, routine machines, artificial intelligences).
  - Urban governance systems typically show **combinations of types** and behaviors of agents, also subsuming institutional models of relationships

- The environment can cover different roles in a MAS model.
  - Traditionally it represents a static field of battle…
  - Yet its reactive attitudes to anthropic processes impacting on natural resources can be raised to proxies of an 'environmental agent‘ toward environmental sustainability path.



A multiagent-based scheme of urban planning governance (Italy)

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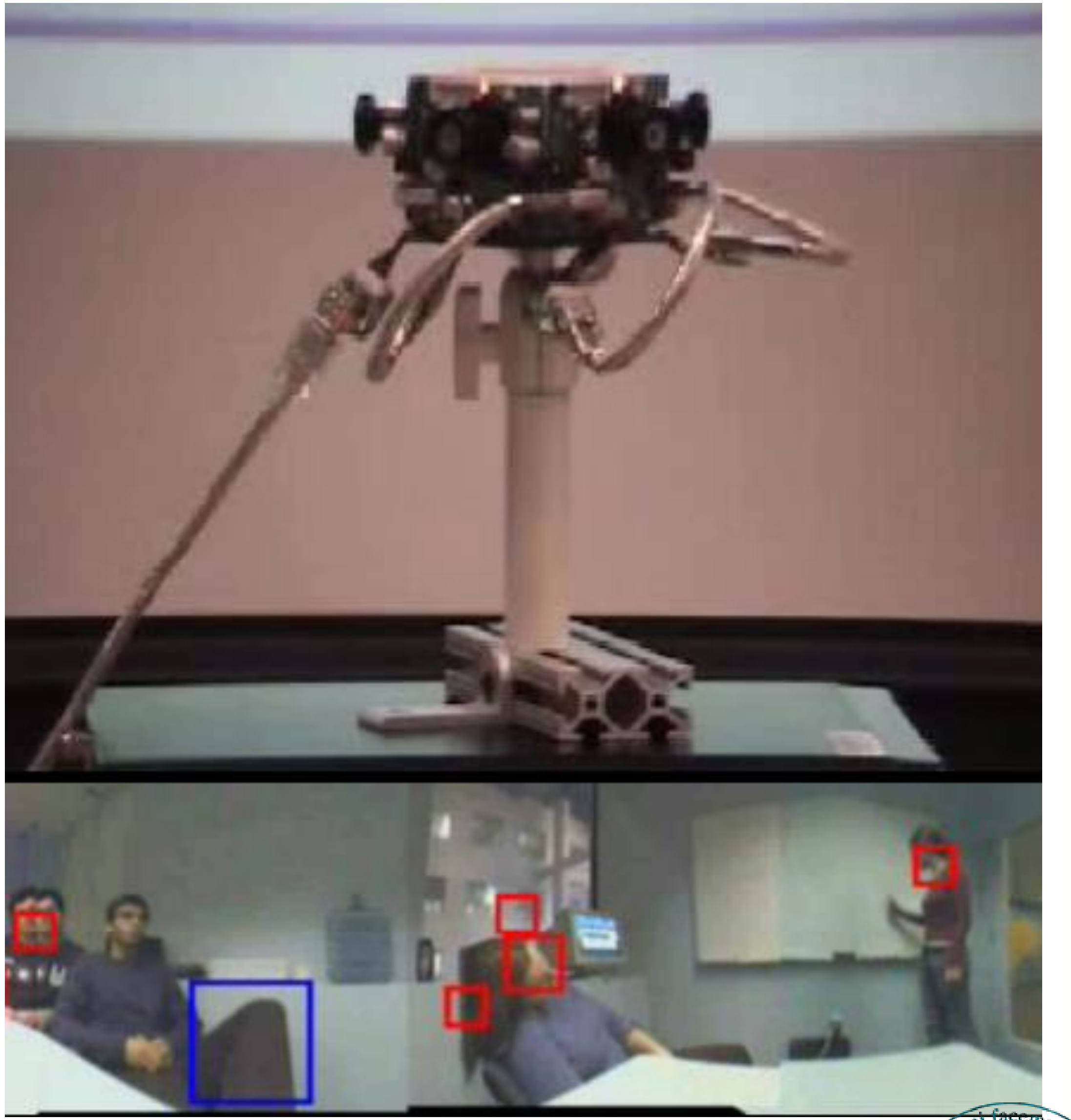
Formalization and modelling of relations

- **Interactions** between agents can take place in **different ways**
  - Human-human interactions can be realized through ICT-based tools or simply through socio-physical contacts
  - Human-artificial or artificial-artificial contacts may require software routines.
- In formal terms, different **relationships** can be supported qualitatively and quantitatively by **rules of a different nature**.
  - A frequent approach is **game theory**
  - Formal relationships can be based on **logical rules** (eg, if-then-else)
  - Various mixes in real life: **hybrid sets** of formal relationships basically reflecting a reality made up of hybrid agents

Inputs acquisition and language formalization

- Knowledge agents need to be supported by an **enriched language**
  - **different technical agents**, tools and sensors that are able to facilitate an appropriate and unambiguous language exchange
  - **integrating written statements** with oral, graphical, gestural etc. languages.

- Languages are often derived from behavior: they express feelings, emotions, ways of being
  - Physical interactions, social networks
- Often informal langage, needing to be integrated into languages that are formalized within the knowledge system architecture.
- This is still an open problem: how to model knowledge?



Tools to collect complex data toward enriched language

SILVENNOINEN, H.: Non-spatial and spatial statistics for analysing human perception of the built environment. ETH Zurich, 2018.
VELOSO, M. M., PATIL, R., RYBSKI, P. E. & KANADE, T.: People detection and tracking in high resolution panoramic video mosaic. In IEEE/RSJ International Conference: Intelligent robots and systems (IROS 2004) (pp. 1323-1328). 2004.

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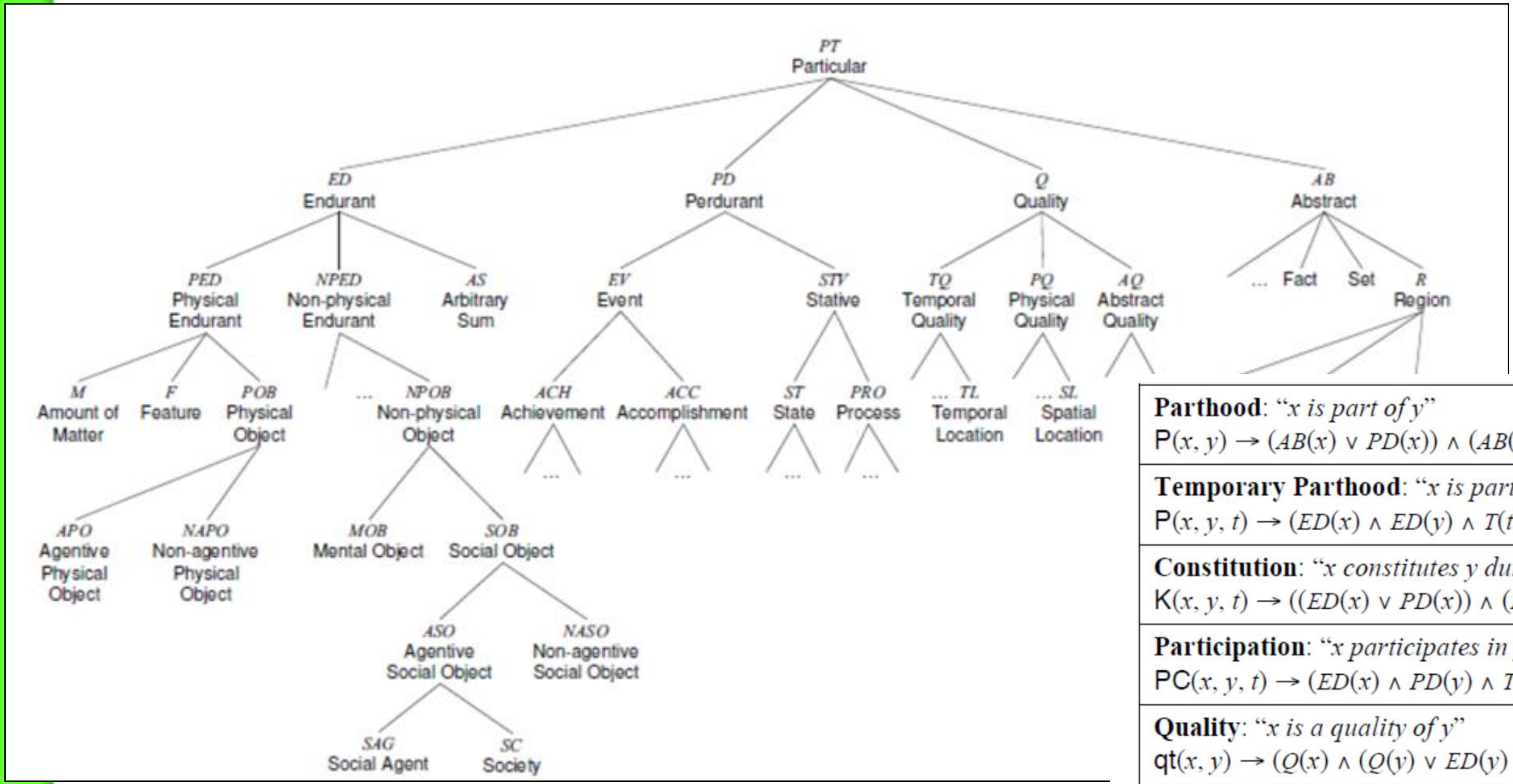
Modelling knowledge structure

- **Contents and formalization** of knowledge are critical points
  - **fuzzy**, uncertain conceptualizations
  - extended conceptualizations, mutually connected among them, and **internally composed** of primitive concepts.
- To manage this complex structure of knowledge, without simplifying it, recent studies propose **formal ontological modelling**
  - Borst defines ontology as “a formal specification of a **shared conceptualization**”
  - The ontological analysis of an abstract city image can be performed via an **applied ontology**.

BORST, W.: Construction of Engineering Ontologies (PhD thesis). Enschede (NL): ITIT, University of Twente. 1997.
GUARINO, N., GANGEMI, A., MASOLO, C., OLTRAMARI, A. & SCHNEIDER, L.: Sweetening Ontologies with DOLCE. In A. Gomez-Perez and V. R. Benjamins (Eds.) Knowledge Engineering and Knowledge Management (pp. 166-181), Berlin: Springer. 2002.



Parthood: "*x is part of y*"
$P(x, y) \rightarrow (AB(x) \vee PD(x)) \wedge (AB(y) \vee PD(y))$

Temporary Parthood: "*x is part of y during t*"
$P(x, y, t) \rightarrow (ED(x) \wedge ED(y) \wedge T(t))$

Constitution: "*x constitutes y during t*"
$K(x, y, t) \rightarrow ((ED(x) \vee PD(x)) \wedge (ED(y) \vee PD(y)) \wedge T(t))$

Participation: "*x participates in y during t*"
$PC(x, y, t) \rightarrow (ED(x) \wedge PD(y) \wedge T(t))$

Quality: "*x is a quality of y*"
$qt(x, y) \rightarrow (Q(x) \wedge (Q(y) \vee ED(y) \vee PD(y)))$

Quale: "*x is the quale of y (during t)*"
$ql(x, y) \rightarrow (TR(x) \wedge TQ(y))$
$ql(x, y, t) \rightarrow ((PR(x) \vee AR(x)) \wedge (PQ(y) \vee AQ(y)) \wedge T(t))$

Taxonomy and axioms of DOLCE ontology.

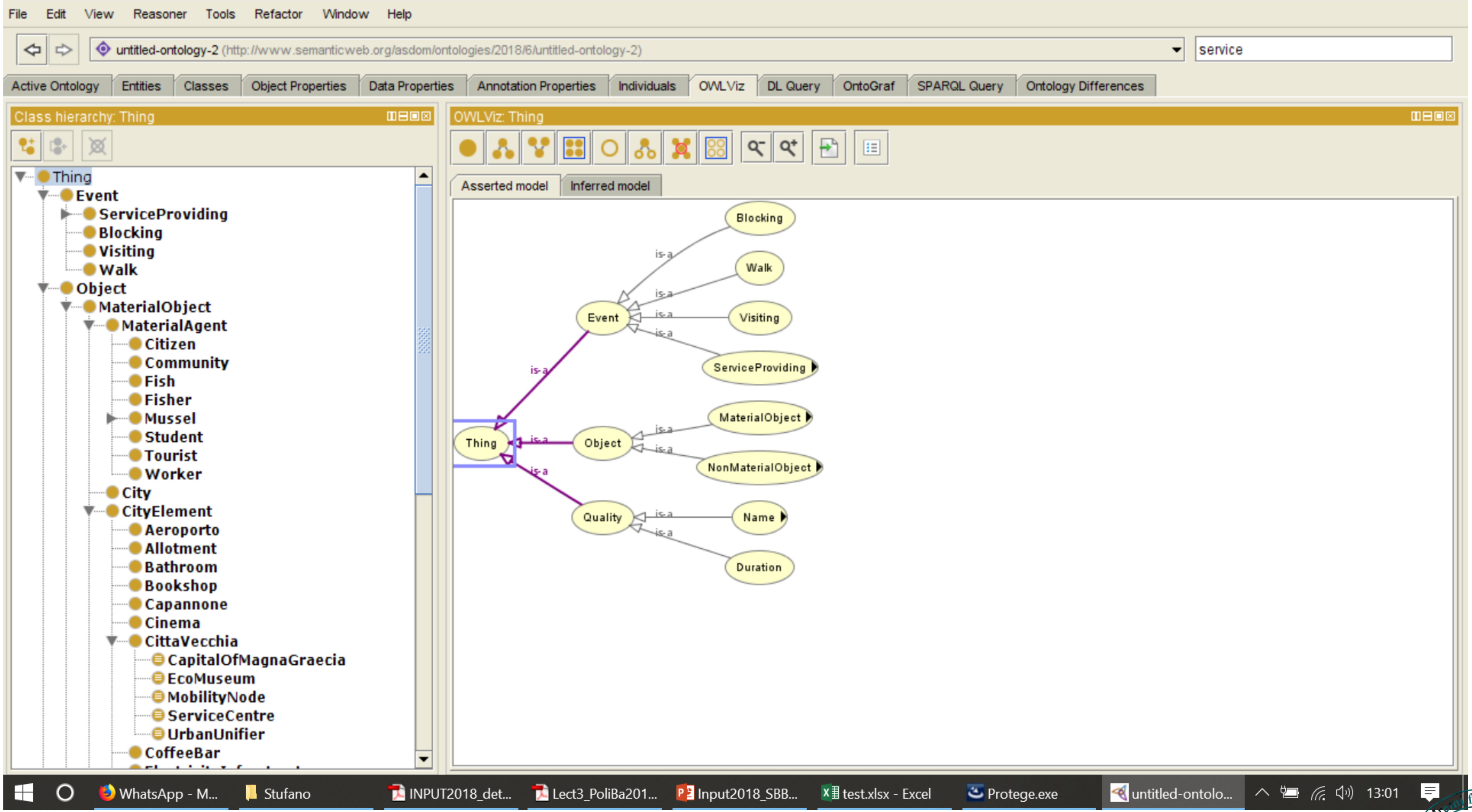
Modelling city ontology

- City is increasingly conceptualized and characterized by a **complex** substance which has a shifting **dynamic** shape.
- **Ontology‘s role is to integrate** different yet coherent world views
  - Ontology is a specification of conceptualizations in a **knowledge domain**.
- A **city definition is not neutral**, depending on the perspective and the ‘original’ state of the definition at hand
  - questions arise on **how many elements** are involved, **what kinds** of elements are involved, what kinds of **languages** are involved.
  - Characterizing the **different types of agents** that are present in an action, with their behaviours.

- A city is made of persons, relations, artifacts: the ontology of a city has to be a kind of **polyhedral conceptual artifact**.
- Apart from what components of a taxonomy should represent the city, there is also a problem of **granularity**
  - for example, **how deep to look** in the city to found the ontological analysis
- A problem of a city conceptualized on its **tangible and intangible**
  - **Places, objects, elements, agents** constantly evolving the image of the city.

Excerpting from a case-study

- The following scheme is the current outcome of an **ongoing project**, as part of the planning process of the city of Taranto (Italy).
- The project is oriented to build a system architecture (DSS) for the management of community knowledge through a reiterated cognitive interaction between citizens, mainly online.
    - It is an argumentative and query-based inferential engine for purposes of decision support on navigation tasks or maintenance of the space itself.
    - The knowledge exchanged in real group argumentation is a critical issue for building realistic planning development scenarios for communities.
- The multiagent/ontological DSS can suggest interesting developments in terms of cognitive connections for operational aims.



Draft ontological representation of Taranto Inner City through Protégé 4.0.

STUFANO, R., BORRI, D., CAMARDA, D., BORGO, S.: Knowledge of places: An ontological analysis of the social level in the city. In R. Papa, R. Fistola & L. Gargiulo (Eds.), Smart Planning, 3-14. Berlin: Springer, 2018.

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Conclusions

- The concept of smart city proposed by this study has a **double-nature** approach
  - enhancing its **complexity-oriented potentials**
  - while pursuing organizational **governance support**.
- A critical **management issue**
  - enhancement of the intelligent, multiagent and proactive management of **continuous knowledge contributions** in urban communities.
- The objective of this study is to **raise interest on ontology**-based knowledge models for the **creation of 'smart' system architectures** for urban planning and management processes.

Follow up

- In a governance-oriented debate, there are **operational questions** of an applied ontology vision:
  - How to maintain a **bottom-up approach** while the essential abstract core (the *spirit of the city*) is **located at the top level** of the ontological hierarchy?
  - How to deal with **multi-agent knowledge mechanisms** ruling the cognitive navigation through the **different hierarchy levels** of city organization?
  - How to deal with **time problems**, i.e. birth, existence, death of cities and their abstract cores (*city spirit*)?
- Follow-up will try to address the above questions, exploring more specifically issues related to the actual building up and management of an **operational system architecture**.

thank you

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