Challenging the Internet of the Future with Urban Computing

Lecturer:
Emanuele Della Valle
emanuele.dellavalle@cefriel.it
http://swa.cefriel.it
http://emanueledellavalle.org

Authors:
Emanuele Della Valle, Irene Celino, Kono Kim, Zhisheng Huang,
Volker Tresp, Werner Hauptmann, and Yi Huang

Agenda

- Introduction
  - Cities are alive
  - Cities face many challenges
  - Addressing Cities challenges with Urban Computing
  - The LarKC project
- Sustainable mobility as an exemplar case of Urban Computing
  - A use case
  - Our previous experience
  - Challenging problems
- Requirements for LarKC
  - Coping with heterogeneity
  - Coping with scale
  - Coping with time-dependency
  - Coping with noisy, uncertain and inconsistent data
- Conclusions
  - Some preliminary ideas
  - A vision for Urban Computing
  - Future works

Cities are alive

- Cities born, grow, evolve like living beings.
- The state of a city changes continuously, influenced by a lot of factors,
  - human ones: people moving in the city or extending it
  - natural ones: precipitations or climate changes

[source http://www.citysense.com]

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Today Cities' Challenges

- Our cities face many challenges

Urban Land Institute

- How can we redevelop existing neighbourhoods and business districts to improve the quality of life?
- How can we create more choices in housing, accommodating diverse lifestyles and all income levels?
- How can we reduce traffic congestion yet stay connected?
- How can we include citizens in planning their communities rather than limiting input to only those affected by the next project?
- How can we fund schools, bridges, roads, and clean water while meeting short-term costs of increased security?

[source http://www.uli.org/]

Urban Computing as a Way to Address them

[source IEEE Pervasive Computing,July-September 2007 (Vol. 6, No. 3)]

Urban Computing

- **A definition**:
  - The integration of computing, sensing, and actuation technologies into everyday urban settings and lifestyles.

[source IEEE Pervasive Computing,July-September 2007 (Vol. 6, No. 3)]

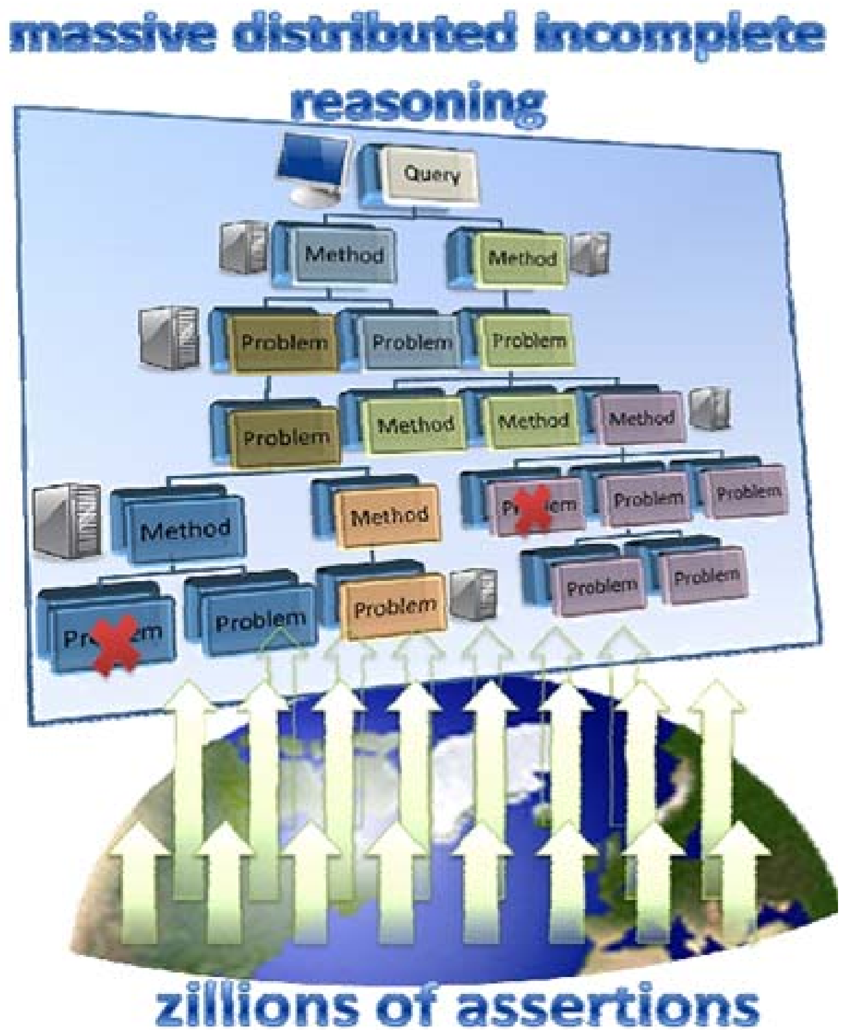
- **Urban settings** include, for example, *streets, squares, pubs, shops, buses, and cafés* - any space in the semipublic realms of our towns and cities.
- Only in the last few years have researchers paid much attention to technologies in these spaces.
- **Pervasive computing** has largely been applied
  - either in relatively **homogeneous rural areas**, where researchers have added sensors in places such as forests, vineyards, and glaciers
  - or, on the other hand, **in small-scale**, well-defined patches of the built environment such as smart houses or rooms.
- **Urban settings are challenging** for experimentation and deployment, **and they remain little explore**d

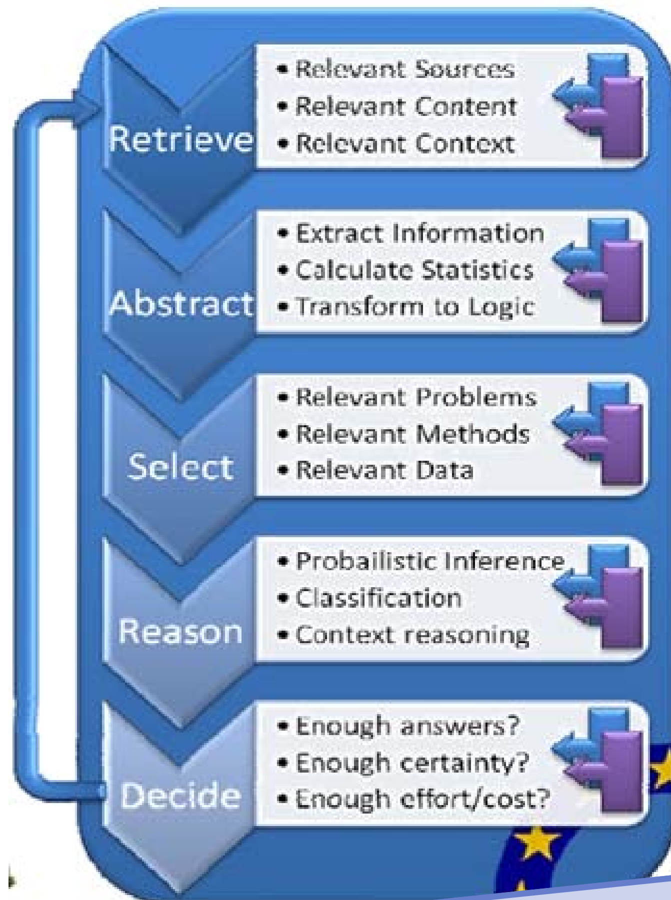
For more information visit http://wiki.larkc.eu/UrbanComputing
Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Availability of Data

- Some years ago, due to the lack of data, solving Urban Computing problems with ICT looked like a Sci-Fi idea.
- Nowadays, a large amount of the required information can be made available on the Internet at almost no cost:
  - maps with the commercial activities and meeting places,
  - events scheduled in the city and their locations,
  - average speed in highways, but also normal streets
  - positions and speed of public transportation vehicles
  - parking availabilities in specific parking areas,
  - and so on.
- We are running a survey (please contribute), see
  - http://wiki.larkc.eu/UrbanComputing/ShowUsABetterWay
  - http://wiki.larkc.eu/UrbanComputing/OtherDataSources

The LarKC project





Visit http://www.larkc.eu !

[Source: Fensel, D., van Harmelen, F.: Unifying reasoning and search to web scale. IEEE Internet Computing 11(2) (2007)]

Sustainable mobility as an example

- **Urban Computing** proposes a set of different **issues**, from **technological** to **social** ones.
- Our experience in the field make us believe that **sustainable mobility is an exemplar case** which we can elicit generalizable requirements from.
- **Mobility demand** has been **growing** steadily for decades and it will continue in the future.
- **For many years**, the primary way of dealing with this increasing demand has been the **increase** of the roadway network **capacity**, by building new roads or adding new lanes to existing ones.
- **However**, **financial and ecological** considerations are posing increasingly severe **constraints** on this process.
- **Hence**, there is a need for additional **intelligent approaches** designed to meet the demand while more efficiently **utilizing the existing infrastructure and resources**.

Urban Land Institute

- How can we redevelop existing neighbourhoods and business districts to improve the quality of life?
- How can we create more choices in housing, accommodating diverse lifestyles and all income levels?
- **How can we reduce traffic congestion yet stay connected?**
- How can we include citizens in planning their communities rather than limiting input to only those affected by the next project?
- How can we fund schools, bridges, roads, and clean water while meeting short-term costs of increased security?

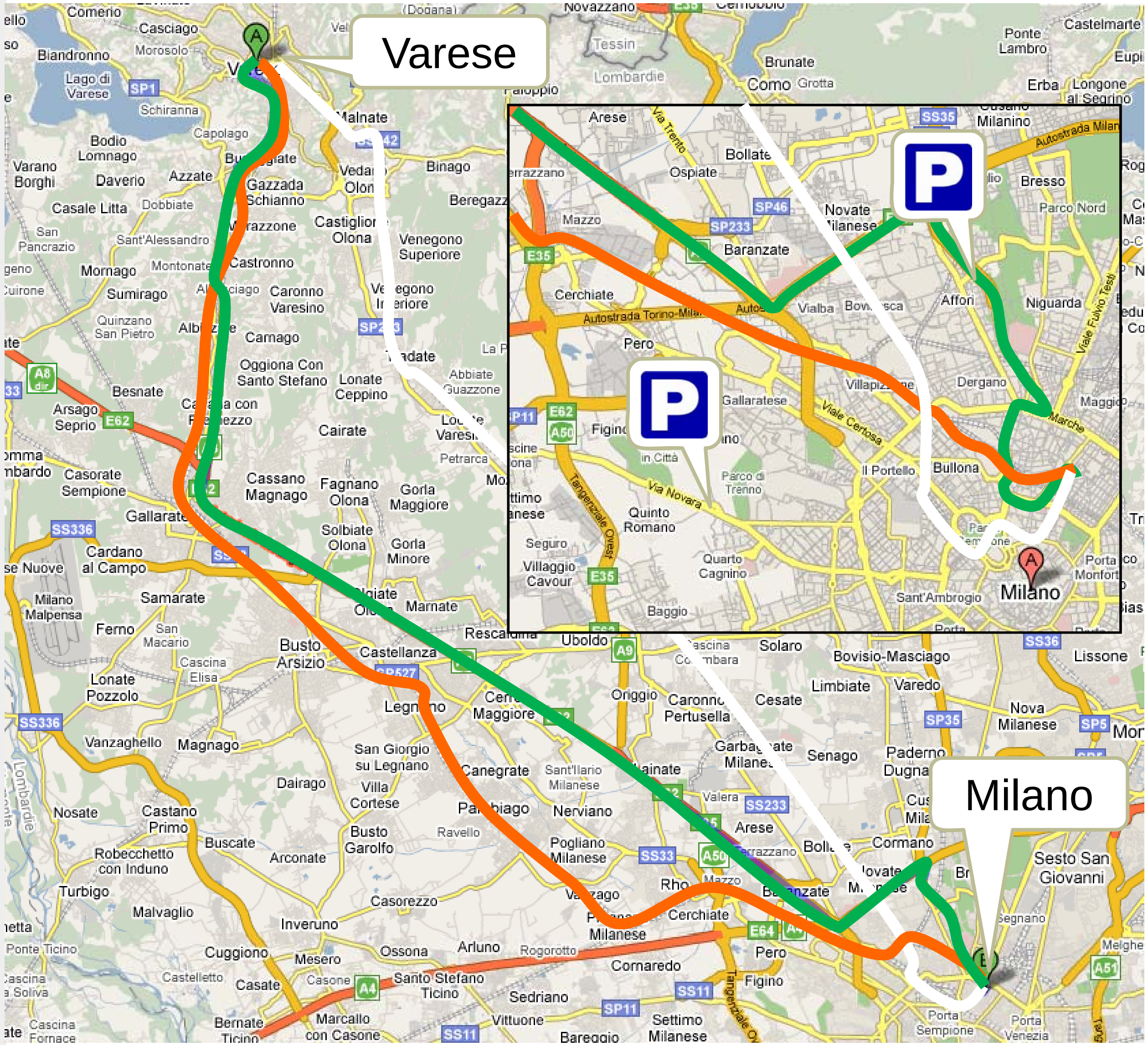
A Challenging Use Case 1/5

Actors:

- Carlo: a citizen living in Varese. The day after, he has to go to Lombardy Region premises in Milano at 11.00.
- UCS: a fictitious Urban Computing System of Milano area

Ways to Milano

- Private Car
- Le Nord railways
- FS railways



For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

A Challenging Use Case 2/5

- Story Board:
  1. He opens the “plan a travel” service of UCS and fills in the required data
     - FROM: via Luigi Sacco, 1 Varese after 8.00 tomorrow
     - TO: via Taramelli, 20 Milano before 11.00 tomorrow
     - **USING**: **any means of transportation**
  2. UCS provides Carlo with three **alternatives**:
     A. **Using railroad** *LeNord* and Metro M3; leaving home at 8.30 and arriving between 10.15 and 10.30.
     B. **Using** an alternative **railroad** *Ferrovie dello Stato* and Metro M3; leaving home at 8.20 and arriving between 10.05 and 10.20.
     C. **Using private car**; leaving home after 9.30 (**when the commuters traffic** on motorway A8 **is almost over**) and arriving between 10.10 and 10.40.
  3. Carlo is tempted by option **C**, he could sleep a little longer, but while traveling by train he could complete the presentation for the meeting, so he chooses the option **A** and he uses the ticket-less option to buy the train ticket.

A Challenging Use Case 3/5

4. Before exiting UCS, Carlo asks to **be alerted if the option he chose will no longer be the best one** (e.g., due to problems to the railroads).
5. The day after at 7.14 **UCS learns from the railroad information system of railroad LeNord** that a technical problem is causing an average delay of 45 minutes to all LeNord trains from Varese to Milano.
6. **UCS estimates** that an accident of such kind will not be solved before 11.00, therefore it checks if any planned travel is at risk. It finds Carlo's travel.
7. UCS checks if the other options it proposed to Carlo are still valid. Apparently they are, so UCS sends an SMS to Carlo informing him that a accident is causing 45 minutes delay for all trains on railroad LeNord and he can
   - use the the railroad Ferrovie dello Stato (option **B**)
   - take his private car, in this case Carlo should convert his train ticket into a daily parking ticket for one of the parking lots of the sub-urban metro stations in Milano.

A Challenging Use Case 4/5

8. Carlo receives the SMS, he enters UCS and checks the two alternatives.
9. He can take option B, but he knows that when problem of this kind happens on LeNord, all commuters take the railroad Ferrovie dello Stato and he will never be able to find a sit. On the other hand, **UCS** (*taking into account weather data through the route and real time traffic congestion status on top of historical traffic congestion statistics*) **predicts** that being a rainy day the **traffic** on A8 will be slower and he should leave around 9.00.
10. Carlo decides to take his car, in this way he has all the time to complete the presentation before leaving.
11. He leaves home around 9.00 and instructs its GPS Navigator to interact with UCS traffic service and to **find the cheapest gas station along the road**. During the driving Carlo receives the instructions for the gas station and refuels the car.

For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

A Challenging Use Case 5/5

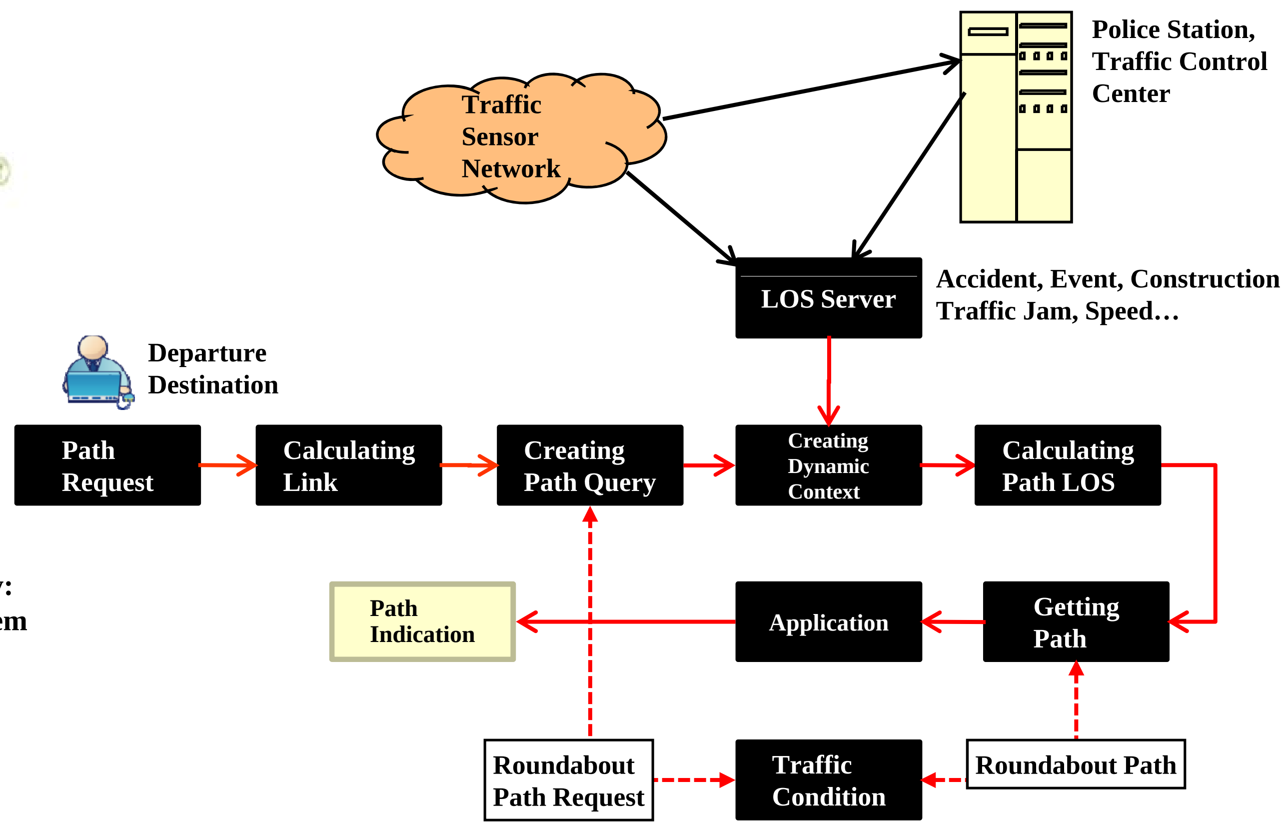
12. At a certain moment Carlo's GPS Navigator **receives a wheather alert** from UCS: Milano North-West area is hit by heavy showers and the traffic is getting slower. *Instead of going to the planned North-West parking lot, the GPS suggests to go to one in the South-West*; the metro from there will only take 10 minutes more than from the planned parking lot, but the estimated time to the planned parking lot is 25 minutes more than the planned one.
13. Carlo considers the option and decides to follow it.
14. Carlo parks the car and taking the metro arrives in time to his appointment.

State-of-the-art in sustainable mobility

- Public authorities have taken steps in the direction to support this use case, but very complex problems have to be solved.
- Control centers for mobility management
  - have to maintain **detailed maps of all transportation networks** (roads, but also metro and railroad lines)
  - requires to **keep track of** all **events** that can alter such networks
  - have to be **connected to different devices** such as inductive loops, cameras, floating car, traffic lights, weather detectors, etc.
  - require **sophisticated tools** for traffic modeling, estimation, prognosis and decision support.
- **Reacting to a Changing Environment is difficult**.
  - **For public authorities** it is impossible to provide continuous, up-to-the-minute information, restrict to a targeted subgroup of drivers. The options *in collective route guidance are essentially “all or nothing”.*
  - **Private actors** (e.g. broadcast media such as Traffic Message Channel) can provide information to modern navigation systems but the reaction of present route guidance systems to delays and incidents is a **short-term and/or small-scale strategy**.
  - **Private cars** are **just one of the possible means of transportation**. Sometimes public transportation can be by far the best choice.

Saltlux implementation experiences

U-City is an integrated, intelligent and innovative new city-making service that works through **city domain convergence based on ubiquitous computing and information communication technology**. It includes an intelligent Traffic Information System



A part of Ubiquitous City:
Traffic Information System

For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

SIEMENS implementation experiences

- The department of learning systems at Siemens Corporate Technology has a lot of research and project experience in the field of traffic modeling and forecasting.
- Since 15 years they have been using machine learning techniques, e.g., fuzzy clustering, neural networks and reinforcement-learning to model, predict and optimize traffic flows.
- See the paper for references.

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Requirements for LarKC

- Urban Computing (and Mobility Management) encompass sensing, actuation and computing requirements.
- Many previous work in the area of Pervasive and Ubiquitous Computing investigated requirements in sensing, actuation, and several aspects of computation (from hardware to software, from networks to devides)
- In this work we are focusing on **reasoning requirements** for LarKC, but also of general interest for the entire community working on the complex relationship of the Internet with space, places, people and content.
- Hereafter **we exemplify** how coping with
  - representational, reasoning, and defaults heterogeneity
  - scale
  - time-dependency
  - noisy, uncertain and inconsistent data

Coping with representational heterogeneity

- It is an **obvious** requirement
  - data always come in **different formats** (syntactic and structural heterogeneity)
  - **legacy data** not in semantic formats will always exist!
  - the problem of **merging and aligning ontologies** is a structural problem of knowledge engineering and it must be always considered when developing an application of semantic technologies.

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Coping with reasoning heterogeneity

It means the systems allow for multiple paradigms of reasoners; e.g.

- **precise and consistent** inference for telling that at a given junction all vehicles, but public transportation ones, must go straight

- **approximate reasoning** when calculating the probability of a traffic jam given the current traffic conditions and the past history.

[source http://senseable.mit.edu/]

Coping with defaults heterogeneity 1/2

Open World Assumption vs. Close World Assumption

- While for the an entire city we cannot assume complete knowledge, for a time table of a bus station we can

[source: http://gizmodo.com/photogallery/trafficsky/1003143552]

LeNORD

IT | EN

Gruppo FNM Malpensa Express Andata e Ritorno Contatti

Consulta Orario

da Varese Casbeno a Milano Cadorna il 27/9/2008 a partire dalle ore 15:49

Soluzioni trovate:

Partenza	Arrivo	Durata	Tipo	Prezzo cl. 1^	Prezzo cl. 2^	Opzioni	
16:09	17:10	61 m		6.25	4.20	Dettagli treno	Dettagli prezzi
17:09	18:25	76 m		6.25	4.20	Dettagli treno	Dettagli prezzi
18:09	19:25	76 m		6.25	4.20	Dettagli treno	Dettagli prezzi

Partenza	Arrivo	Durata	Tipo	Prezzo cl. 1^	Prezzo cl. 2^	Cambi	Opzioni	
16:09	17:15	66 m		6.25	4.20	Milano Bovisa	Dettagli trasporto	Dettagli prezzi

Partenza	Arrivo	Durata	Tipo	Prezzo cl. 1^	Prezzo cl. 2^	Cambi	Opzioni	
16:09	17:20	71 m		6.25	4.20	Milano Bovisa	Dettagli trasporto	Dettagli prezzi
17:09	18:28	79 m		N/A	4.20	Milano Bovisa	Dettagli trasporto	Dettagli prezzi

Partenza	Arrivo	Durata	Tipo	Prezzo cl. 1^	Prezzo cl. 2^	Cambi	Opzioni	
17:09	18:33	84 m		6.25	N/A	Milano Bovisa	Dettagli trasporto	Dettagli prezzi

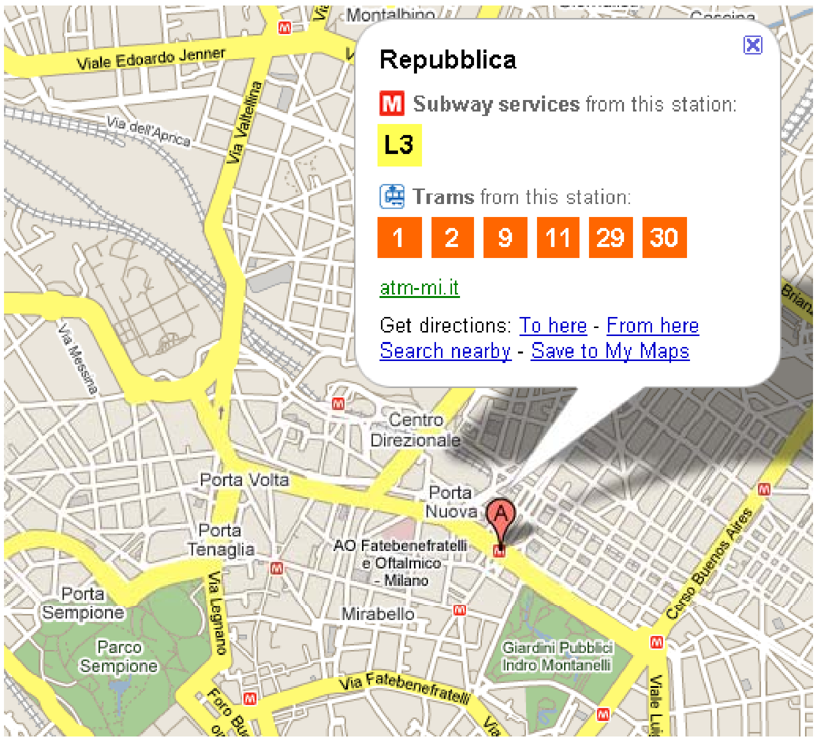
For more information visit http://wiki.larkc.eu/UrbanComputing

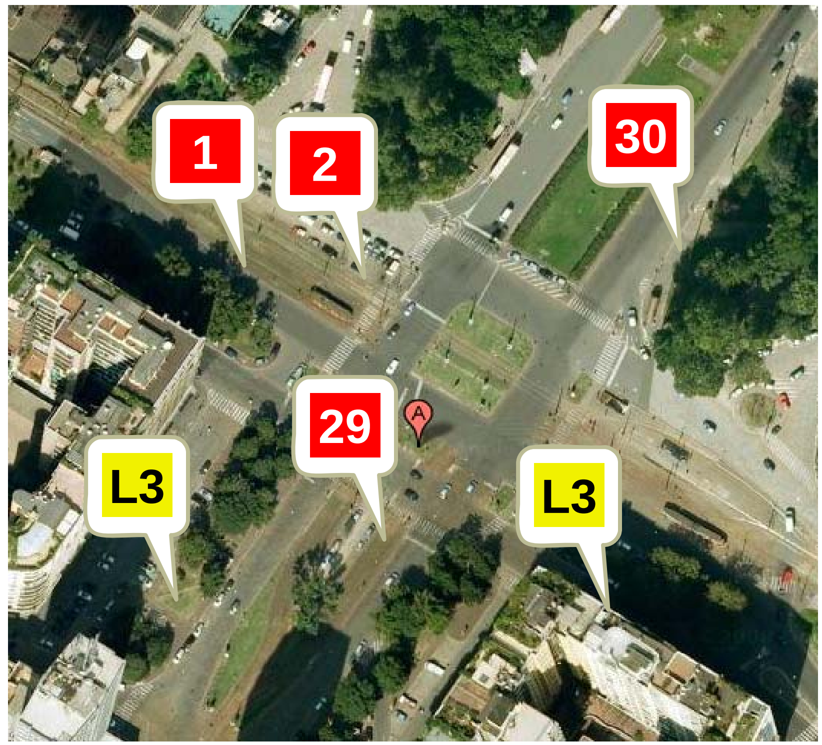
Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Coping with defaults heterogeneity 2/2

Unique Name Assumption

- A square with several station for buses and subway can be considered a unique point for multimodal travel planning, but not when the problem is giving direction in that square to a pedestrian





For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Coping with scale

- The advent of Pervasive Computing and Web 2.0 technologies led to a **constant**ly **growing amount of data** about urban environments (see slide 7)
- Although we encounter large scale data **which are not manageable**, it does not necessary mean that we have to deal with all of the data simultaneously.
- Usually, **only very limited amount data are relevant** for a single query/processing at a specific application.
- For example, when Carlo is driving to Milano,
  - only part of the Milano map data are relevant.
  - the local parking information may become active by a prediction of the known relation between bad weather conditions and destination parking lot re-planning.

For more information visit http://wiki.larkc.eu/UrbanComputing
Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Coping with time-dependency

- **Knowledge and data can change over the time**.
  - For instance, in Urban Computing names of streets, landmarks, kind of events, etc. change very slowly, whereas the number of cars that go through a traffic detector in five minutes changes very fast.
- This means that the system must have the **notion of "observation period**", defined as the period when we the system is subject to querying.
- Moreover the system, **within a given observation period**, must consider the following **four different types of knowledge and data**:
  - **Invariable knowledge**
  - **Invariable data**
  - **Periodically changing data** that change according to a temporal law that can be
  - **Event driven changing data** that are updated as a consequence of some external event.

For more information visit http://wiki.larkc.eu/UrbanComputing
Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Invariable knowledge and data

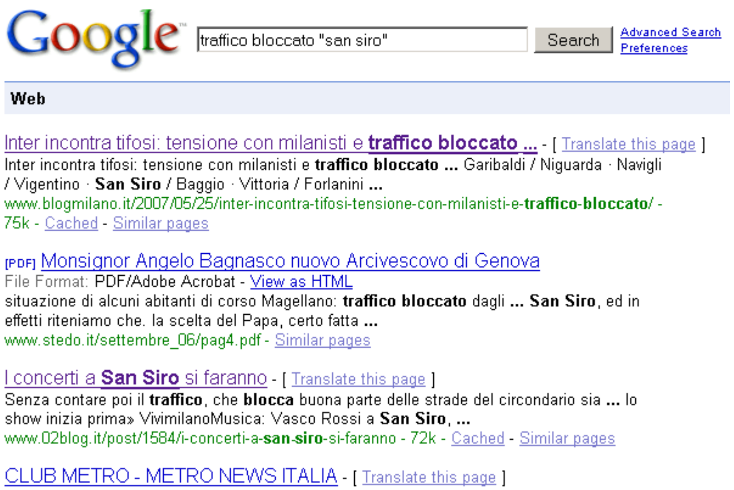
- **Invariable knowledge**
  - it includes obvious **terminological knowledge**
    - such as an address is made up by a street name, a civic number, a city name and a ZIP code
  - less obvious **nomological knowledge** that describes **how the world is expected**
    - **to be**
      - e.g., given traffic lights are switched off or certain streets are closed during the night
    - **to evolve**
      - e.g., traffic jams appears more often when it rains or when important sport events take place
- **Invariable data**
  - do not change in the observation period, e.g. the names and lengths of the roads.

For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Changing data

- **Periodically changing data** change according to a temporal law that can be
  - **Pure periodic law**, e.g. every night at 10pm Milano overpasses close.
  - **Probabilistic law**, e.g. traffic jam appear in the west side of Milano due to bad weather or when San Siro stadium hosts a soccer match.
- **Event driven changing data** are updated as a consequence of some external event. They can be **further characterized by the mean time between changes**:
  - **Slow**, e.g. roads closed for scheduled works
  - **Medium**, e.g. roads closed for accidents or congestion due to traffic
  - **Fast**, e.g. the intensity of traffic for each street in a city



Google traffico bloccato "san siro" Search Advanced Search Preferences

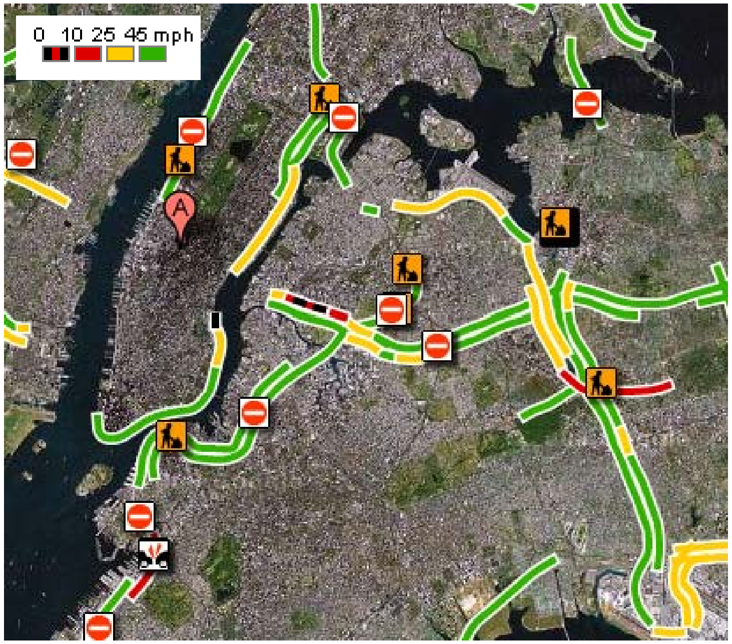
Web

Inter incontra tifosi: tensione con milanisti e **traffico bloccato** ... - [Translate this page]
Inter incontra tifosi: tensione con milanisti e **traffico bloccato ...** Garibaldi / Niguarda · Navigli / Vigentino · **San Siro** / Baggio · Vittoria / Forlanini **...**
www.blogmilano.it/2007/05/25/inter-incontra-tifosi-tensione-con-milanisti-e-**traffico-bloccato**/ - 75k - Cached - Similar pages

[PDF] Monsignor Angelo Bagnasco nuovo Arcivescovo di Genova
File Format: PDF/Adobe Acrobat - View as HTML
situazione di alcuni abitanti di corso Magellano: **traffico bloccato** dagli **... San Siro**, ed in effetti riteniamo che. la scelta del Papa, certo fatta **...**
www.stedo.it/settembre_06/pag4.pdf - Similar pages

I concerti a **San Siro** si faranno - [Translate this page]
Senza contare poi il **traffico**, che **blocca** buona parte delle strade del circondario sia **...** lo show inizia prima» VivimilanoMusica: Vasco Rossi a **San Siro**, **...**
www.02blog.it/post/1584/i-concerti-a-**san-siro**-si-faranno - 72k - Cached - Similar pages

CLUB METRO - METRO NEWS ITALIA - [Translate this page]



For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Coping with Noisy, uncertain and inconsistent data

- **Traffic** data are a **very good example** of such data.
- **Different sensors observing the same road area give apparently inconsistent information**.
  - a traffic **camera** may say that the road is **empty**
  - whereas **an inductive loop** traffic detector may tell **100 vehicles** went over it
  - **The two information may be coherent** if one consider that a traffic camera transmits an image per second with a delay of 15-30 seconds, whereas a traffic detector tells the number of vehicles that went over it in 5 minutes and the information may arrive 5-10 minutes later.
- Moreover, a **single data coming from a sensor in a given moment may have no certain meaning**.
  - an inductive loop traffic detector, it it tells you 0 car went over
    - Is the road empty?
    - Is the traffic completely stuck?
    - Did somebody park the car above the sensor?
    - Is the sensor broken?
  - Combining multiple information from multiple sensors in a given time window can be the only reasonable way to reduce the uncertainty.

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Some partial solutions we are working on

- Within the LarKC, we are envisioning a set of partial solutions to address the challenges of Urban Computing including:
  - **Traffic Prediction** using recurrent neural networks
  - **Data Scheduling** to address scalability
  - **Stream Reasoning** to address time-dependency.

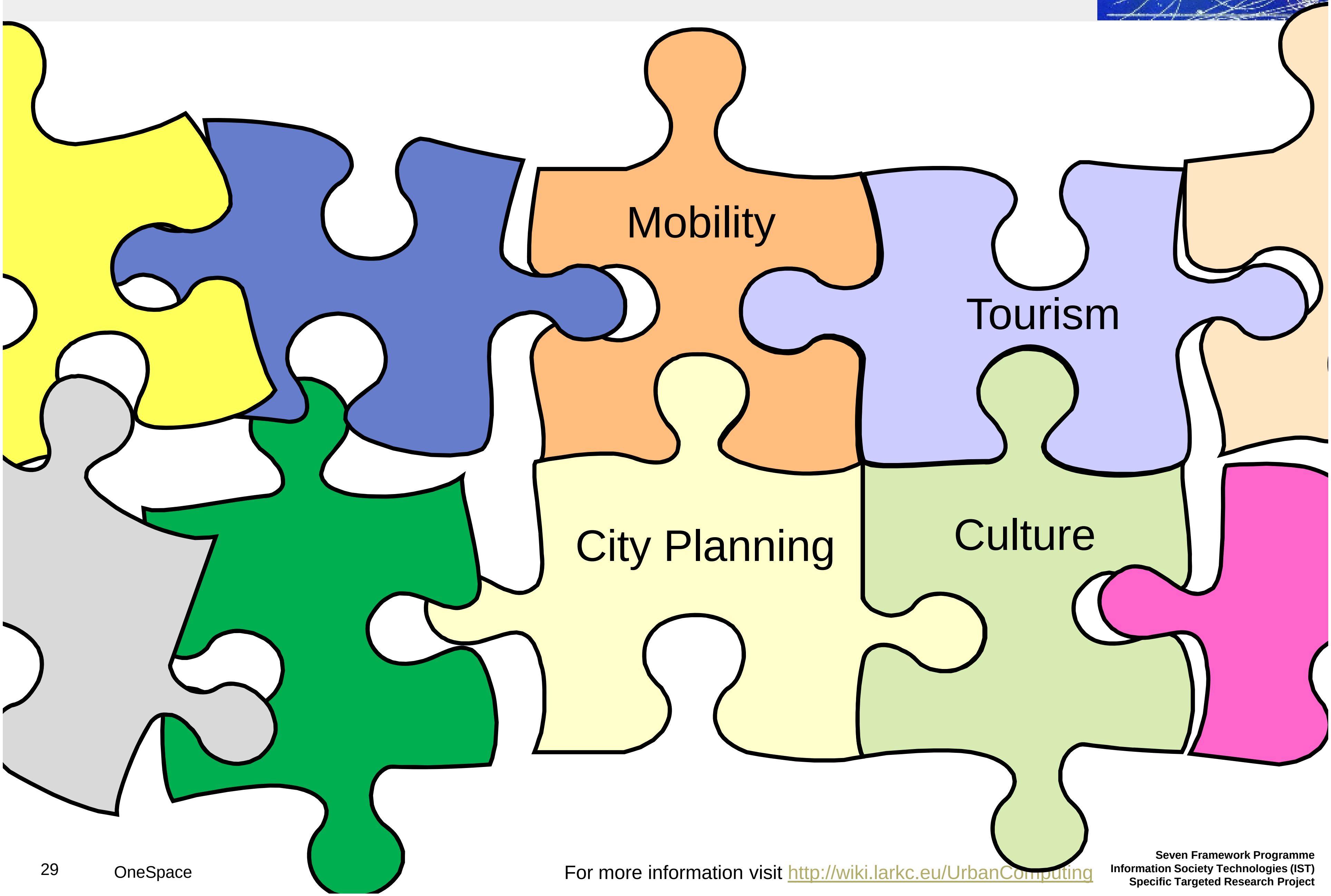
Monday September 29
A First Step Towards Stream Reasoning
E. Della Valle, S. Ceri, D. Barbieri, D. Braga and A.Campi

FIS:2008 future internet symposium

For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Vision for Urban Computing



For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Thank you for paying attention

Any Questions?

For more information visit http://wiki.larkc.eu/UrbanComputing

Seven Framework Programme
Information Society Technologies (IST)
Specific Targeted Research Project

Challenging the Internet of the Future with Urban Computing

Lecturer:

Emanuele Della Valle
emanuele.dellavalle@cefriel.it
http://swa.cefriel.it
http://emanueledellavalle.org

Authors:
Emanuele Della Valle, Irene Celino, Kono Kim, Zhisheng Huang,
Volker Tresp, Werner Hauptmann, and Yi Huang