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Making sense of sensor data using ontology: A discussion for road vehicle classification

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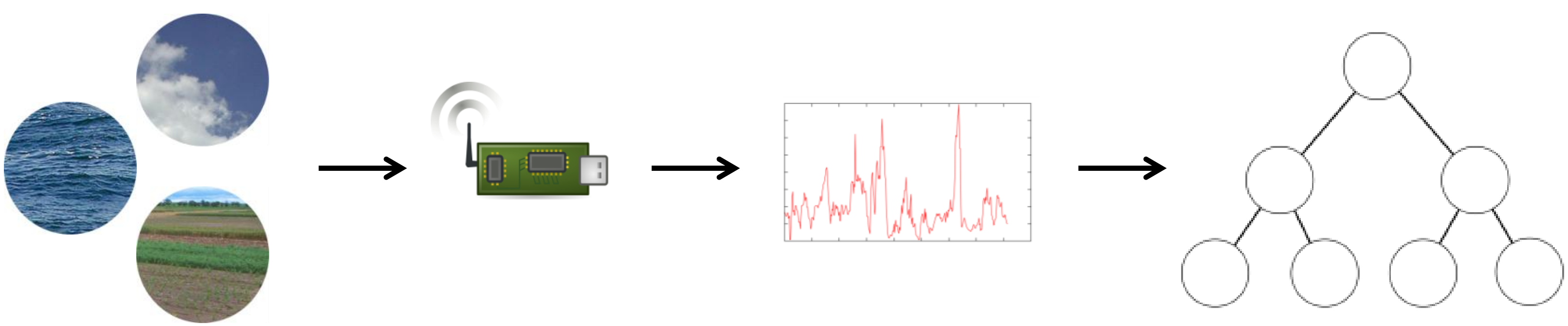
Introduction
Aim

- Automated representation of knowledge
  - About road vehicles driving on a specific road section
  - For which pavement vibration is measured
- Generally, automated representation of knowledge
  - About real-world phenomena, e.g. objects, people, events
  - For which properties are measured using sensors



Introduction
Why

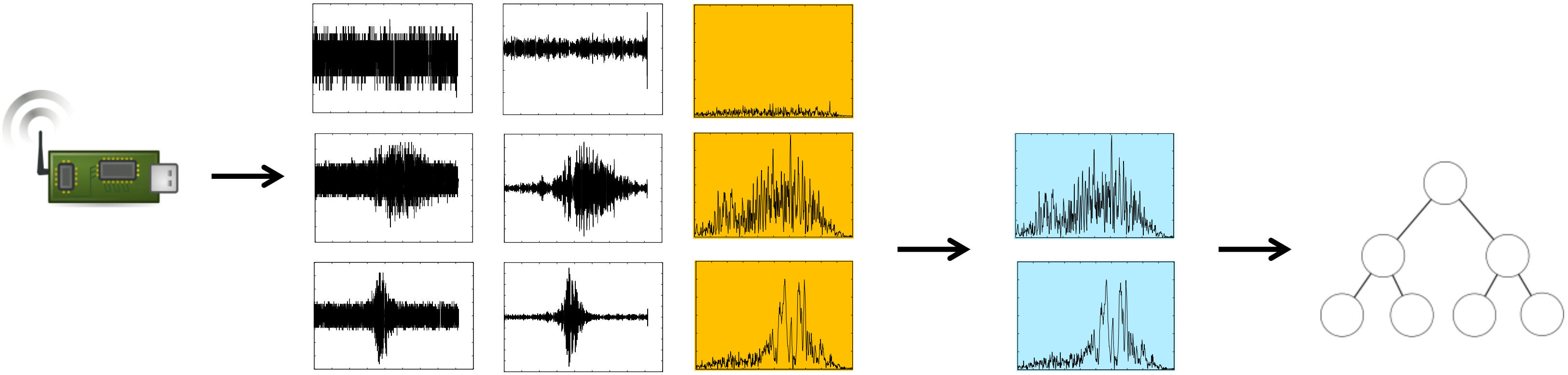
- Sensor data
  - Often high-volume numerical imprecise and incomplete time series
  - Challenging data processing and management
  - Perhaps of little interest to information services
- Abstract concepts and relations
  - How people make sense of the world
  - Of interest to information services
- Considerable gap between sensor data and abstract concepts
  - Reduce it by means of computational methods
  - Signal analysis, machine learning, knowledge representation

Materials and methods
Materials

- Data acquisition on August 30, 2011 between 10 AM and 4 PM
- Sensors
  - Three vibration sensors installed at side of a road section
    - About 130 million measurement values
  - Camera to visually monitor the road section
    - About 25 thousand image files
- Semantic Sensor Network Ontology[10]
  - Represent knowledge about
    - Observations made by sensors
    - For vehicles and their properties
- WEKA[9], Protégé[11], Jena[12]

Materials and methods
Methods

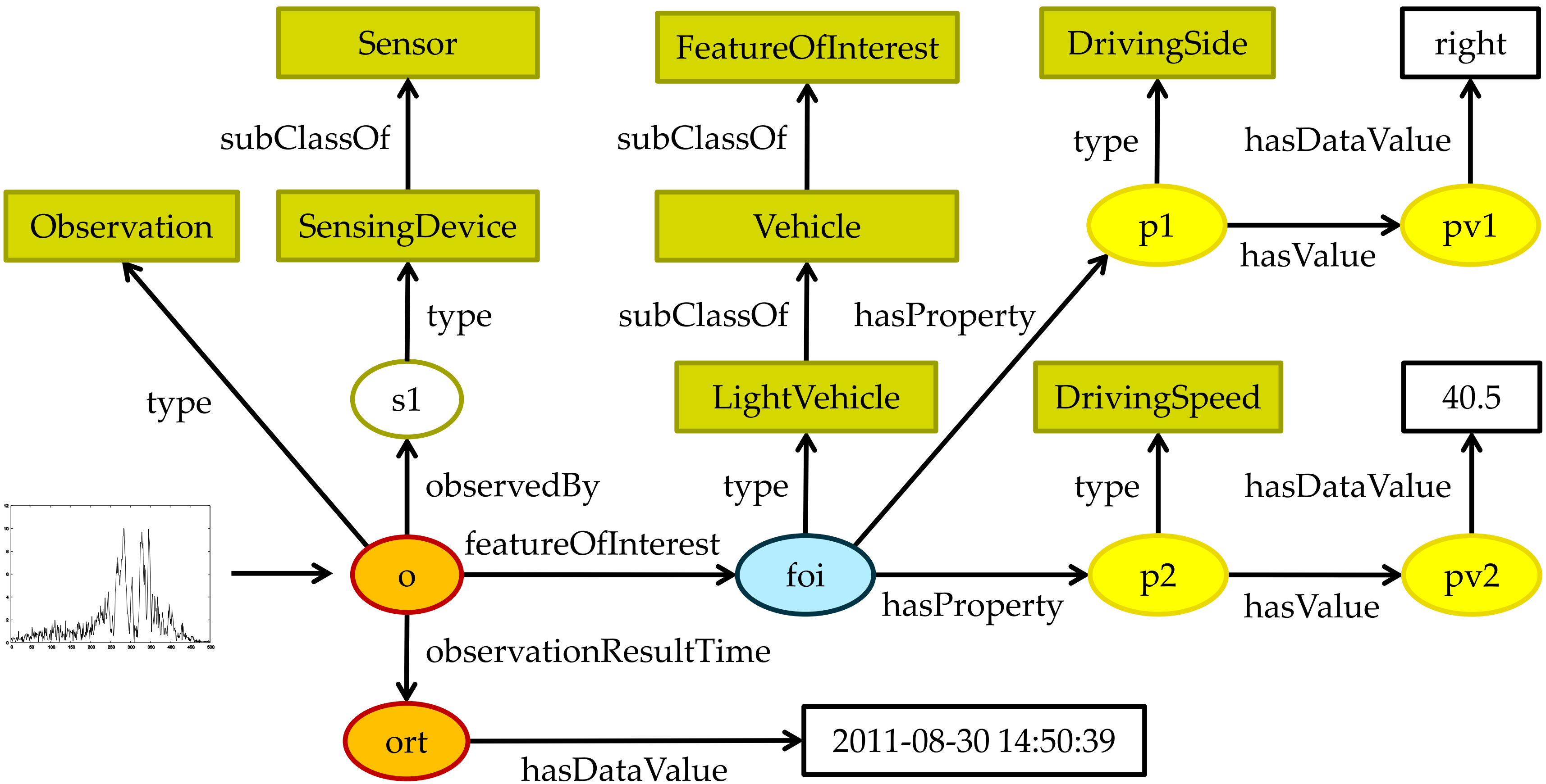
- Camera images to visually identify vehicles
- Labeled datasets to train neural network classifiers; each second
  - Bandpass filter and Fourier transform ~8 s of data
  - Heuristic decision whether a vehicle was observed
  - Label vibration data and use it as training examples
- Given trained classifiers, do



Results
Classification performance

	Sensors		
Task	**S1**	**S2**	**S3**
Vehicle detection	92%	95%	96%
Vehicle classification	82%	75%	83%

Results
Knowledge representation and reasoning



Discussion

- Abstraction from measurement data
  - Knowledge layer with high-level domain terminology
  - Hide data processing complexity from information services
  - Better suited for users
- Retaining versus discarding measurement data
  - Alternative, semantic annotation of measurement data
  - Generic and inference, but only within expressivity of the language
- Limitations of the presented approach
  - Costly implementation, machine learning and programming
  - Domain specific, vision for a generic framework

Related work

- Vehicle detection/classification for traffic monitoring[1,2,3]
- Semantic annotation of sensor data[4]
- Terminologies to describe sensors and sensor networks[5]
- System architectures akin to what we presented here[6,7,8]
- Pervasive computing systems[13]
- Cognitive robotic systems[14]

Conclusions

- For vehicle classification using road-pavement vibration sensors
  - Gap between raw sensor data and abstract domain terminology
  - Benefits of reducing the gap and make sense of sensor data
  - Achieve this aim using state-of-the-art computational methods
    - Including knowledge representation and reasoning
- Perhaps more generally of interest to
  - Environmental information systems that build on sensor networks
  - Such as systems for,
    - Lake and watershed monitoring
    - Forest fire monitoring
    - Atmospheric science, specifically aerosol monitoring

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