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Institute for Geoinformatics
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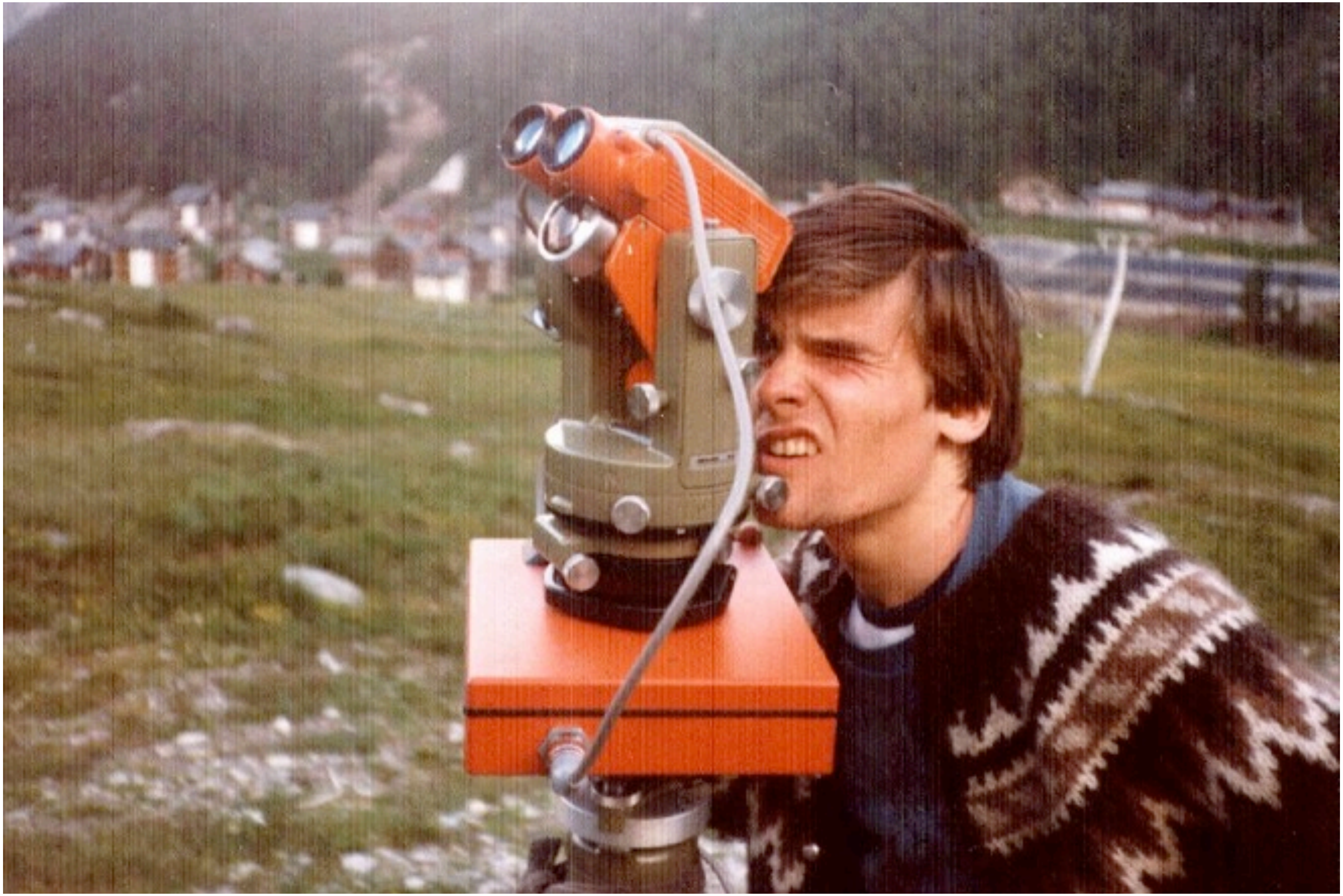
Ontology of Observations in Space and Time

Werner Kuhn

Muenster Semantic Interoperability Lab (MUSIL)
as of Nov 1: UCSB Center for Spatial Studies



A world full of sensors

Some Problems to Solve

1. sensor networks are often disconnected from the web
   - true: bus locations, water quality, agricultural data, ...
   - false: weather, traffic, food, ...
2. even if they are connected, or with observations in general, it is hard to
   - interpret somebody else's observations
   - abstract over sensor observations (aggregate, generalize)
   - link sensor data to process models
3. sensor standards emphasize technology and syntax, not information and semantics of observations.

Missing: Support to find data and reason about sensed phenomena

- Reference Use Cases of W3C:
  A. Device discovery: find device(s) that meet given criteria
  B. Data discovery: find data meeting certain criteria (e.g. temporal and spatial constraints)
  C. Process/provenance: Describe and exploit information about how the data has been or can be collected to support other operations like composition of resources or diagnostics

- Today, we can at best deal with A, because
  - ...standards treat sensing as a technical rather than an information process
  - ...we lack ontologies of many sensed phenomena
  - ...both hinders reasoning with sensor data (e.g. event reasoning)

A Human Sensor Example

"Is this a meadow, a field, or a vacant lot?"

Sensing as Information Process

vacant lot - - - - - - - - refer to - - - - - - - -> 

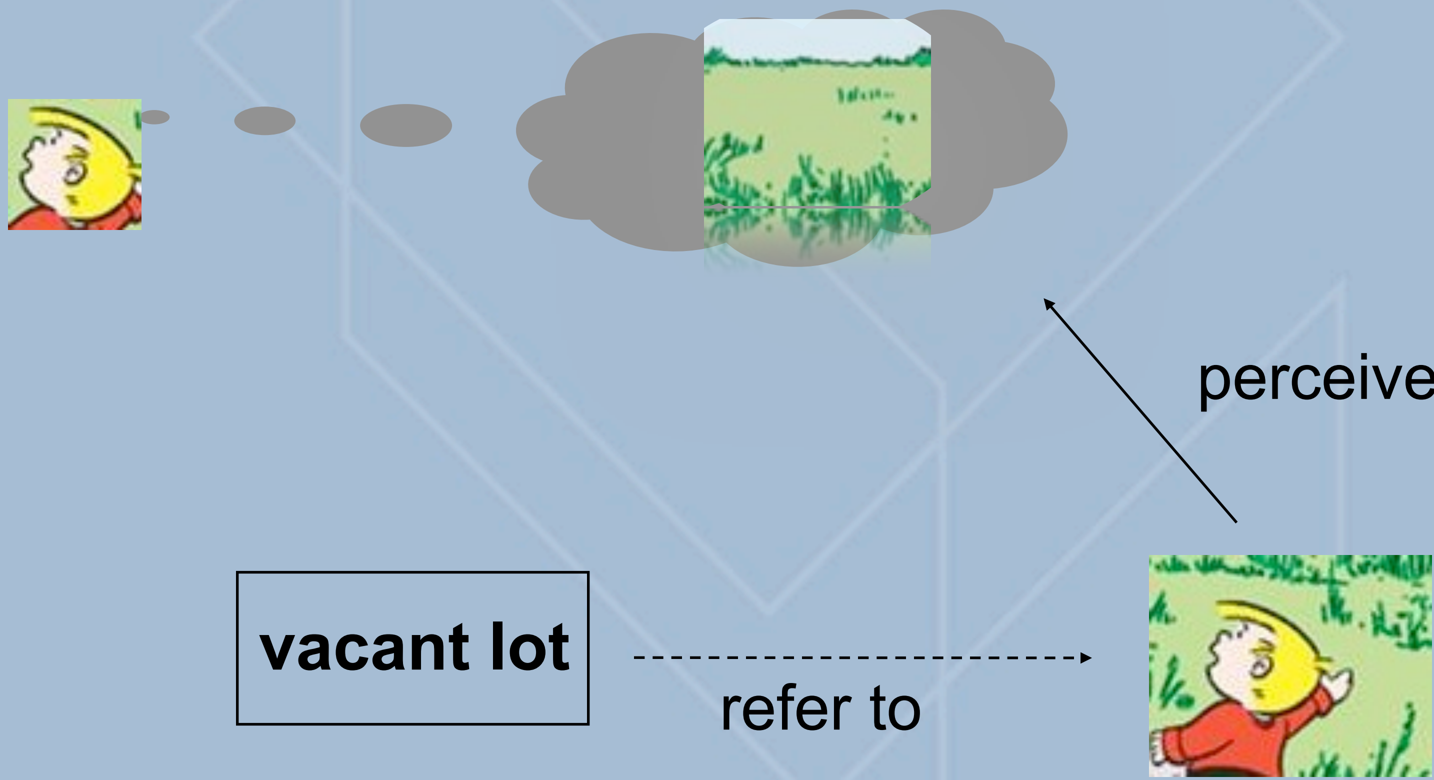
Sensing as Information Process

perceive

vacant lot

refer to

Sensing as Information Process



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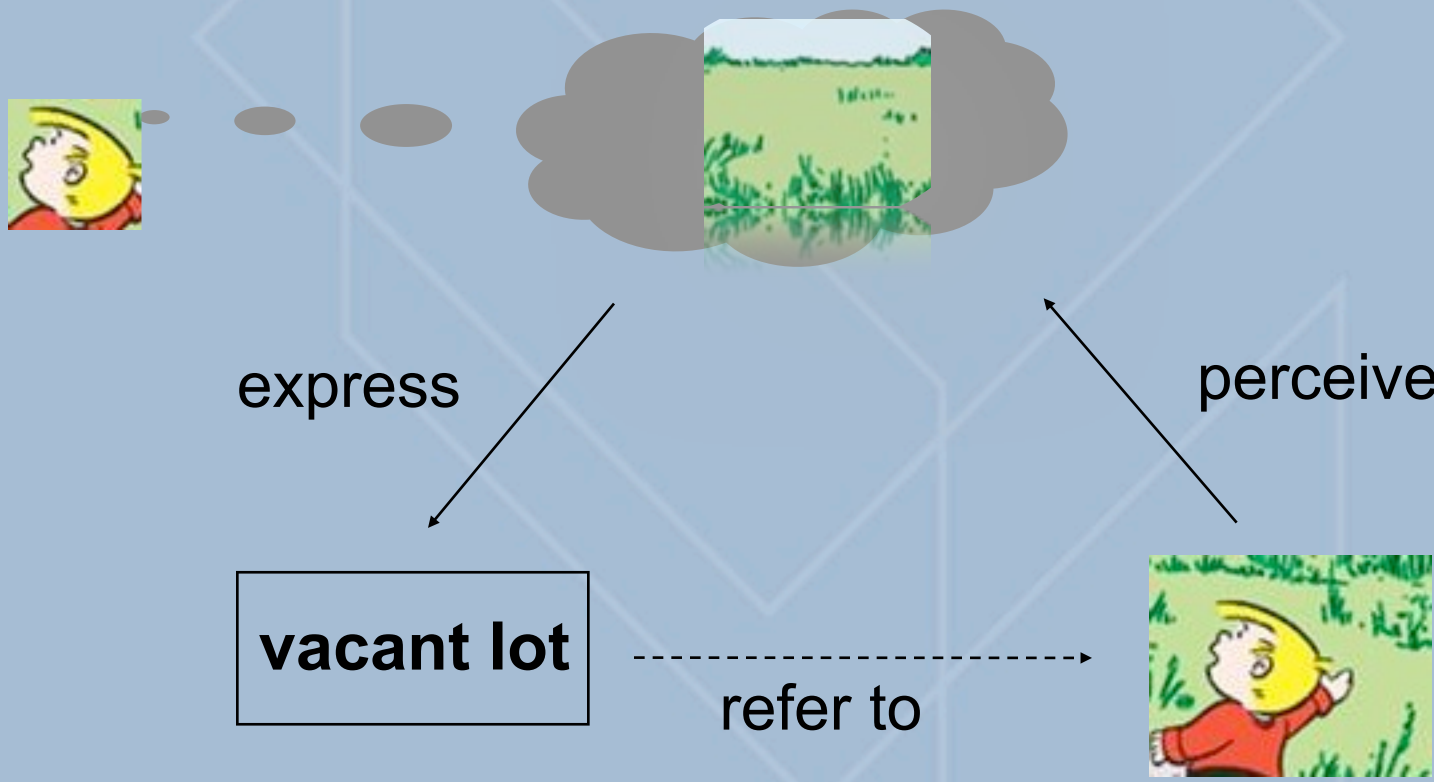

Structuring Observations with DOLCE

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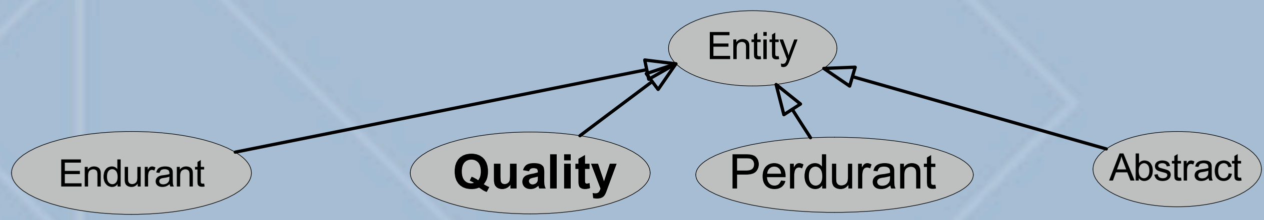

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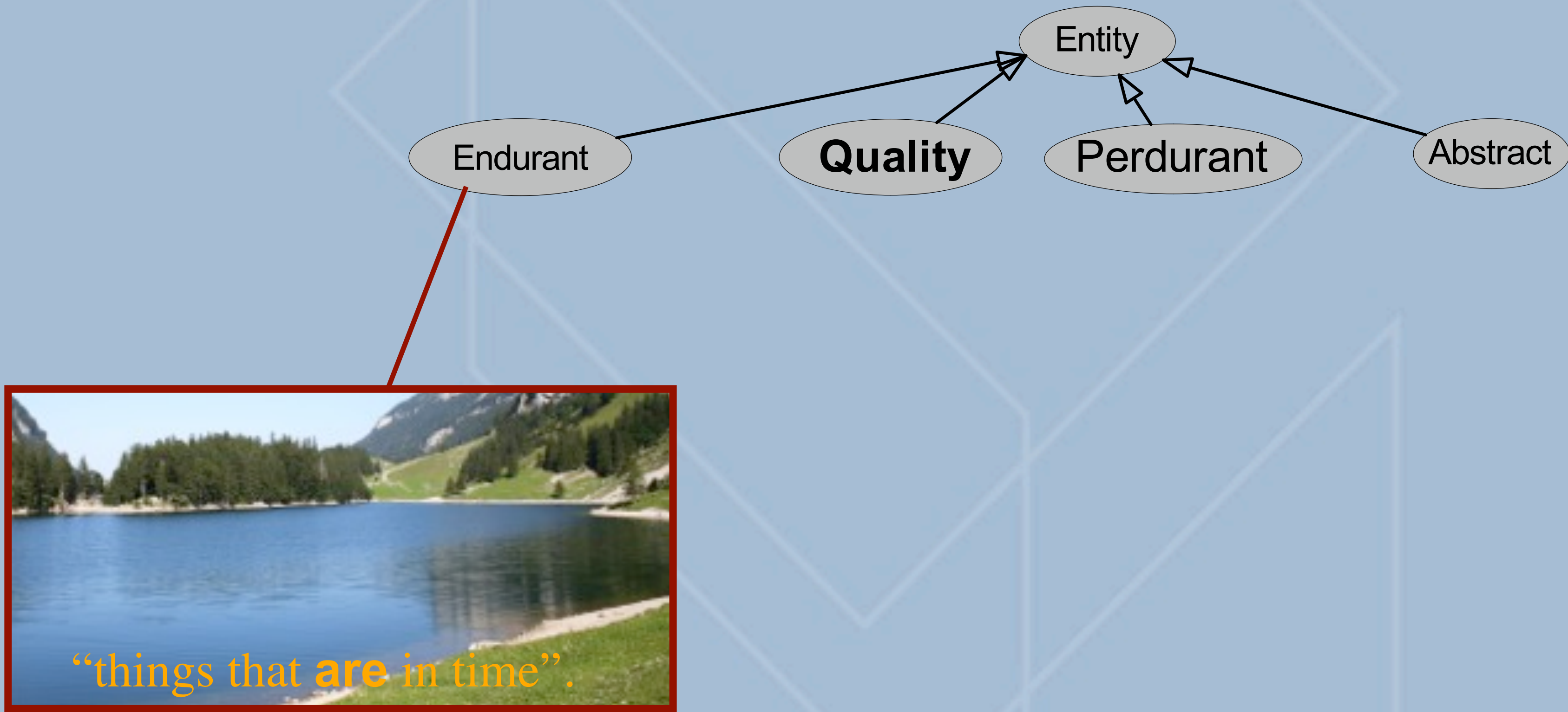

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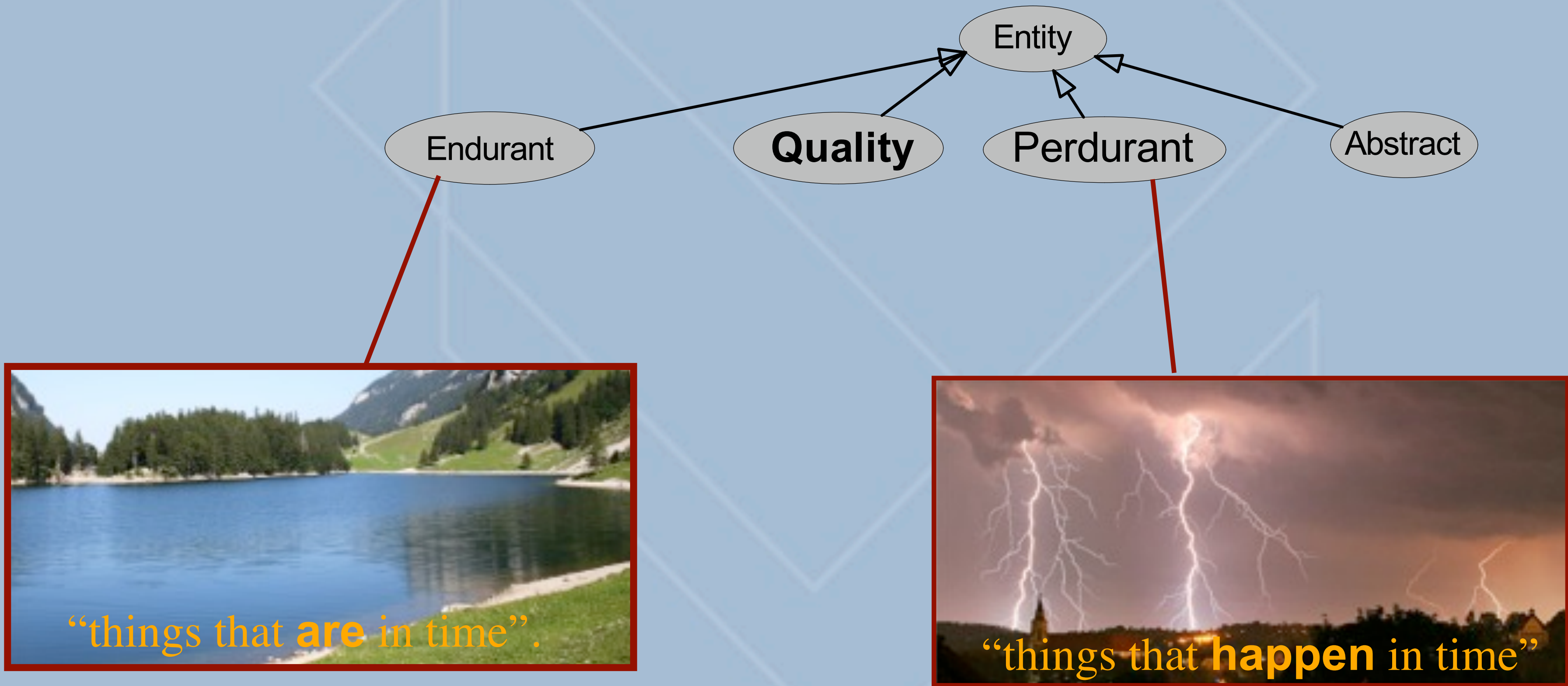

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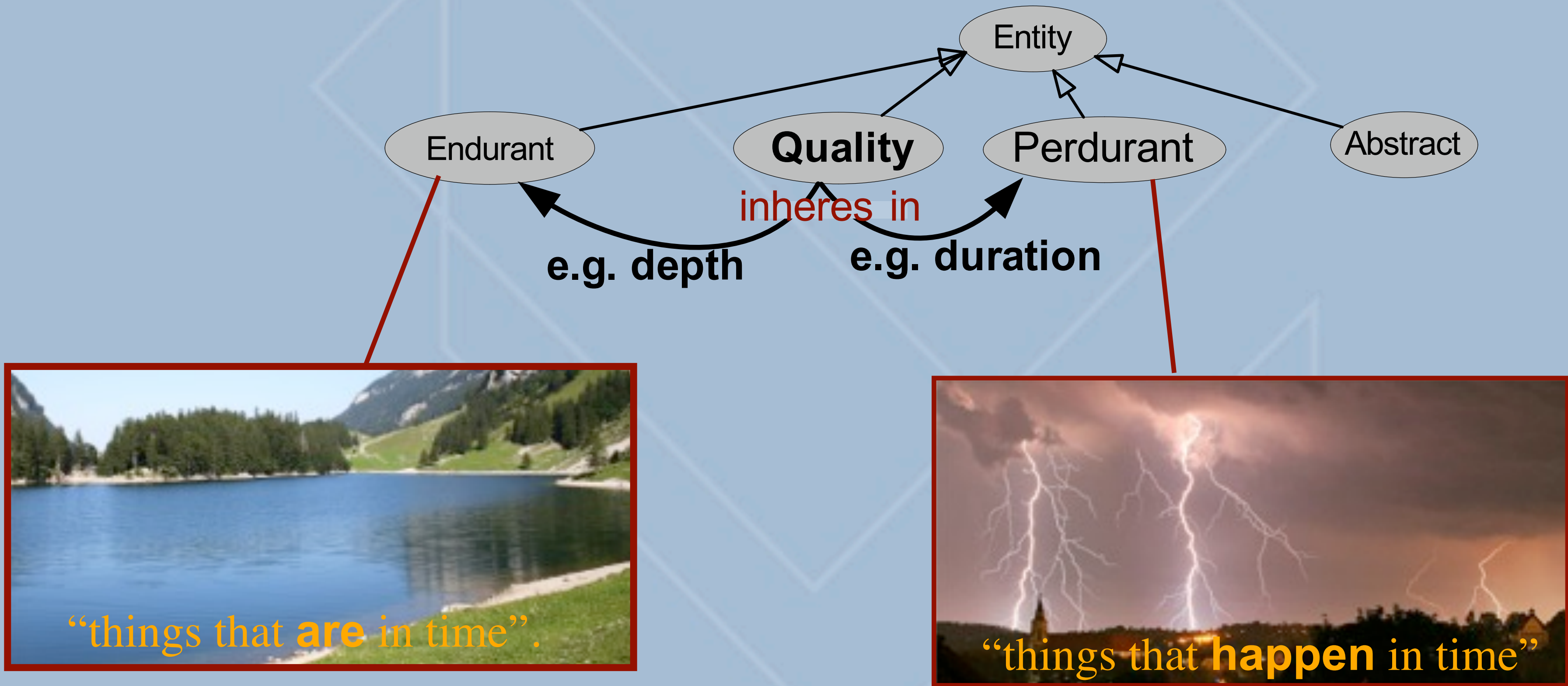

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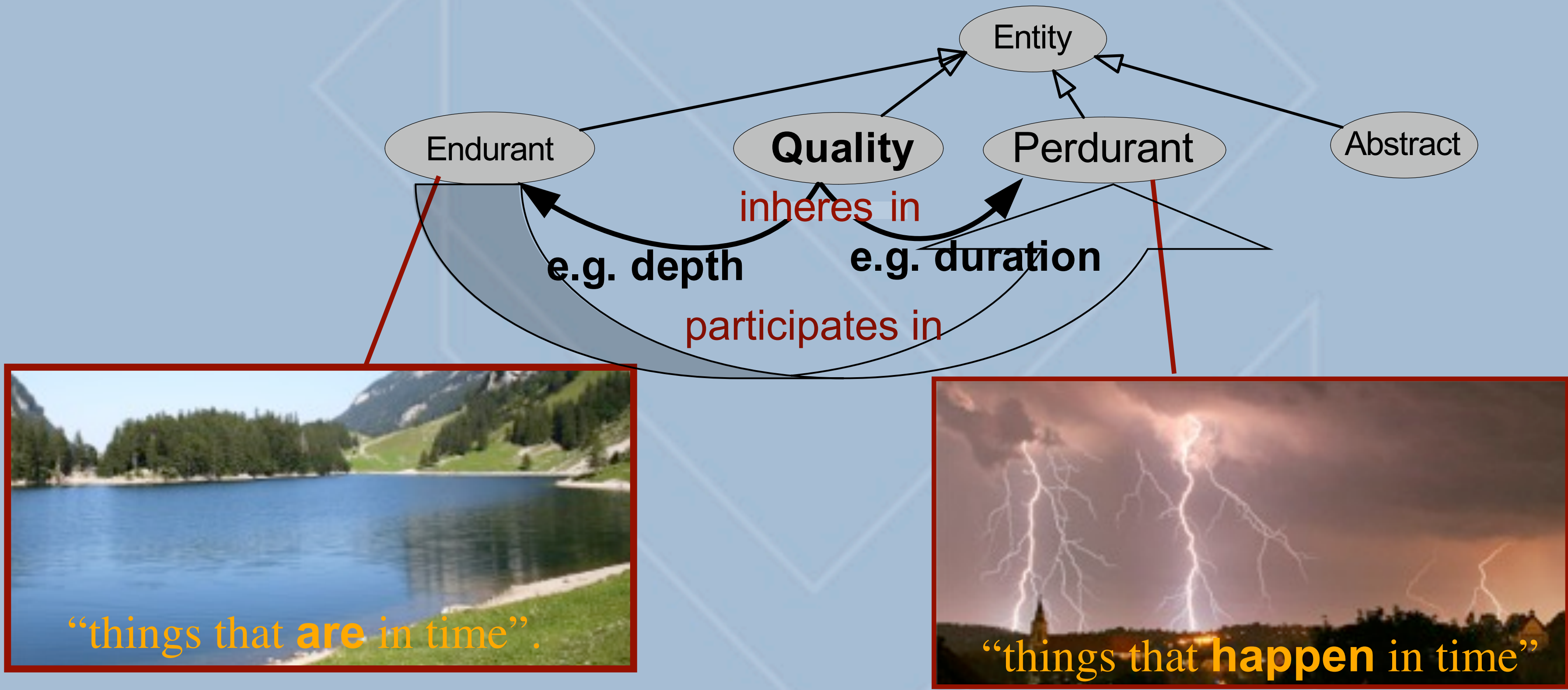
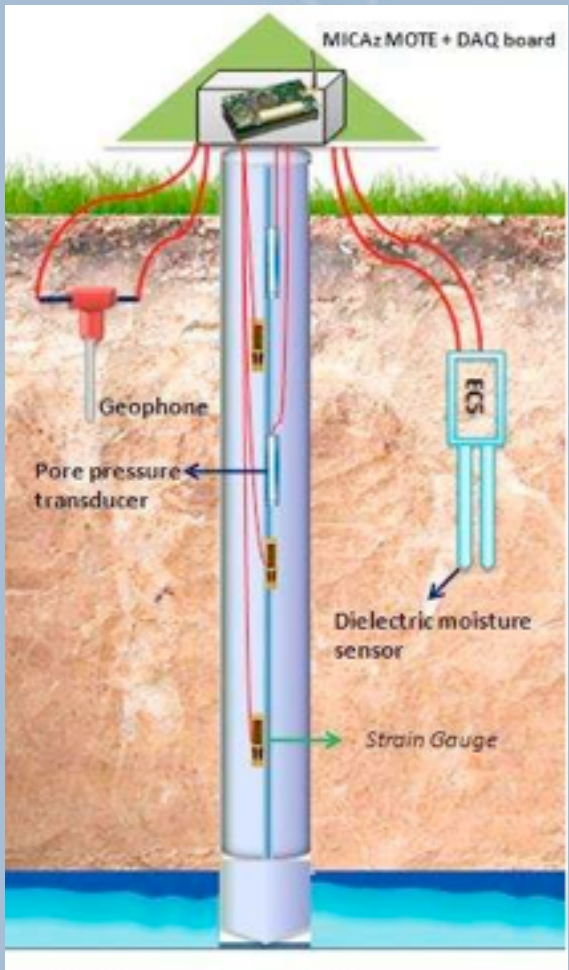


Observation as an Information Process

"An Observation is an action with a result which has a value describing some phenomenon" [OGC]



It assigns symbols to qualities of endurants or perdurants.

We have produced a generic **observation ontology**, abstracting from sensor technology and focusing on **information processes**

[see Kuhn 2009, GeoS proceedings]

The Functional Ontology of Observation and Measurement (FOOM)

1. commits to DOLCE's four top level categories
2. uses DOLCE's notion of quality spaces and its extension by reference spaces [Probst]
3. clarifies OGC sensor standards terminology
   phenomenon: observable quality (of endurant, perdurant, or quality)
   feature of interest: endurant or perdurant
4. generalizes sensors to include humans, animals
   in fact, it generalizes human observations to include technical ones
5. generalizes qualities to include affordances [Ortmann]
6. written as an algebraic specification and simulation in Haskell.

Qualities

Qualities are what agents perceive.

DOLCE provides the notion of quality and reference spaces [Gärdenfors, Masolo, Probst].

The class of all quality types (= properties) is modelled as a constructor class in Haskell:

```
class QUALITIES quality entity

instance QUALITIES Temperature AmountOfAir
instance QUALITIES Humidity AmountOfAir
instance QUALITIES Height Step
...
```

Stimuli

Stimuli ("detectable changes") are perdurants.

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class (QUALITIES quality entity, APOS agent)
    => STIMULI quality entity agent where
       perceive :: quality entity -> agent -> agent
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       perceive :: quality entity -> agent -> agent

instance STIMULI Temperature AmountOfAir Person where
    perceive (Temperature amountOfAir) person =
       person {pQuale = heat amountOfAir}
```

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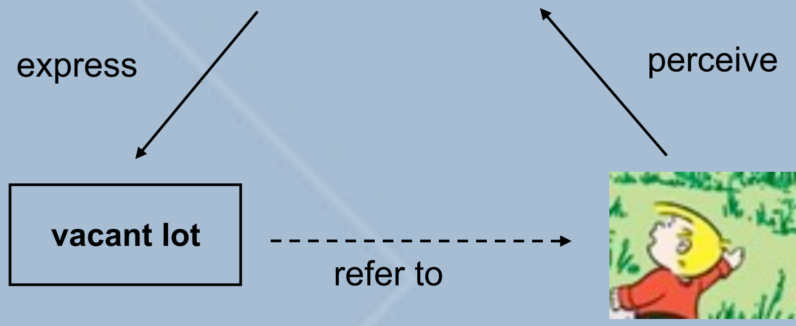
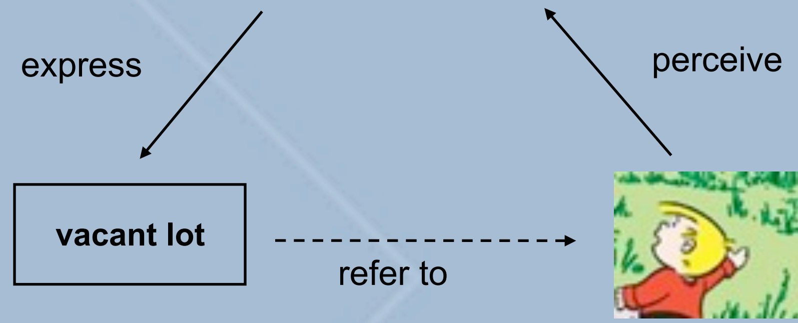
Observations



To observe is to perceive a quality and then express the quale.

Observations



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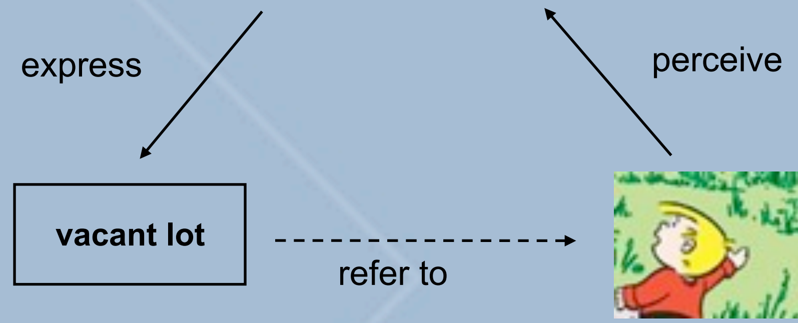

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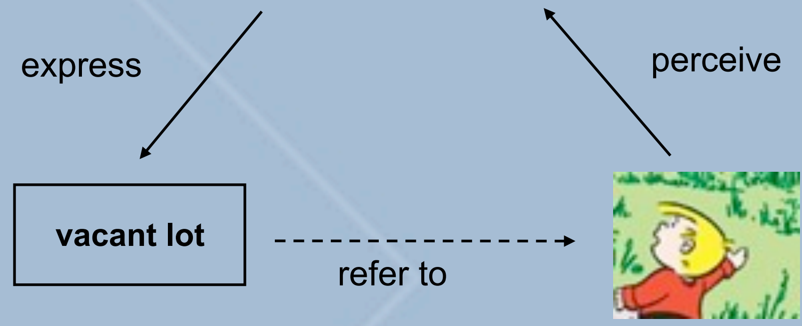

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class (STIMULI quality entity agent)
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instance OBSERVATIONS Temperature AmountOfAir Person where
  observe (Temperature amountOfAir) person =
    person {pValue = if (pQuale (perceive (Temperature amountOfAir)
    person)) > 15 then "warm" else "cold"}.
```
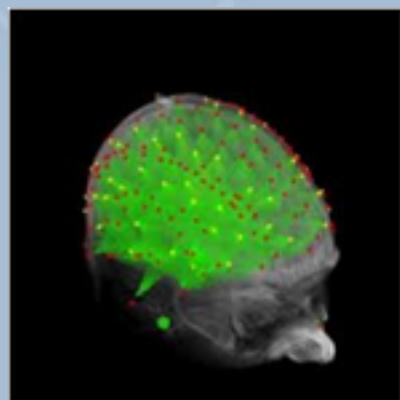

Some Findings

1. stimuli and qualia get “abstracted away”
   no need to specify them, but they are the glue of the ontology
2. qualities and their bearers (endurants, perdurants) are human constructions
3. interoperability requires storing minimal constructions
   then make abstractions explicit
4. linked data with ontology design patterns provide the right modeling flexibility
5. Think big about observations!
   e.g., genomes as observations of trajectories of species

Images as Observations

1. coverage functions **x** → **z**   (left total)
2. treat as single observations (of fields) or as aggregates of observations
3. interpret as images of objects, surfaces, events
4. distinguish spatially intensive from spatially extensive observables (fields vs objects)
5. boundaries are enemies of semantic interoperability



Ongoing and Future Work

1. model spatial and temporal granularity and accuracy
   simple: quality-bearing endurants define spatial granularity
   sophisticated: spatio-temporal convolution
2. model the thematic granularity
   as part of a semantic datum
3. compute semantic datum transformations
4. extend to social qualities
   trust and reputation
5. treat position and time as observables
   simple: the endurants and perdurants bearing observed qualities
   sophisticated: support, containment, path, before ... relations
6. specify perception-action cycles with sensors and actuators
   use them to calibrate semantics of observations.

Conclusions

- Sensors are *the* future source of data
  - especially if including humans (and animals) as sensors
  - but current standards treat them as a technology, rather than as an information source (the “aboutness” is missing)
- The FOOM sensor observation ontology addresses semantic issues
  - qualities inhere in endurants and perdurants
  - stimuli carry signals to the sensor
  - semantic datums translate signals to values
- OGC Semantic Enablement Service connects FOOM to Spatial Data Infrastructures
- W3C incubator connects it to the Semantic Sensor Web.

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NEW CUYAMA
Population 562
Ft. above sea level 2150
Established 1951
TOTAL 4663

Thank You! Questions?

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http://musil.uni-muenster.de/

http://spatial.ucsb.edu/

http://www.ogcnetwork/swe

http://sensorweb.uni-muenster.de

http://www.w3.org/2005/Incubator/ssn/XGR-ssn-20110628/

http://geog.ucsb.edu/~jano/SSN-XG_SensorOntology.pdf

Kuhn, W., 2009. A Functional Ontology of Observation and Measurement. K. Janowicz, M. Raubal, and S. Levashkin (Eds.):*GeoSpatial Semantics · Third International Conference (GeoS 2009), Mexico City, 3-4 December 2009.* Springer-Verlag Lecture Notes in Computer Science 5892: 26–43.

The FOOM ontology in Haskell is currently under revision