When TEDDY meets GrizzLY: Temporal Dependency Discovery for Triggering Road Deicing Operations

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Motivations

An important economic issue . . .

- Road network is a key infrastructure for a highly connected and just-in-time economy.
- An important part of the public works.



. . . with non negligible impacts.

- Environmental impact (e.g., organism and plants)
- Health impact to urban population (e.g., contamination of the ground water).
- Degradation of technical equipment (e.g., salt tend to cause coursing, rusting the steel of vehicles, bridges).

Limitations:

Road operators rely on weather forecasting:

- Weather alerts are on the scale of an entire urban area.
- Topographic and urban disparities can cause differences in temperature and freezing phenomena.

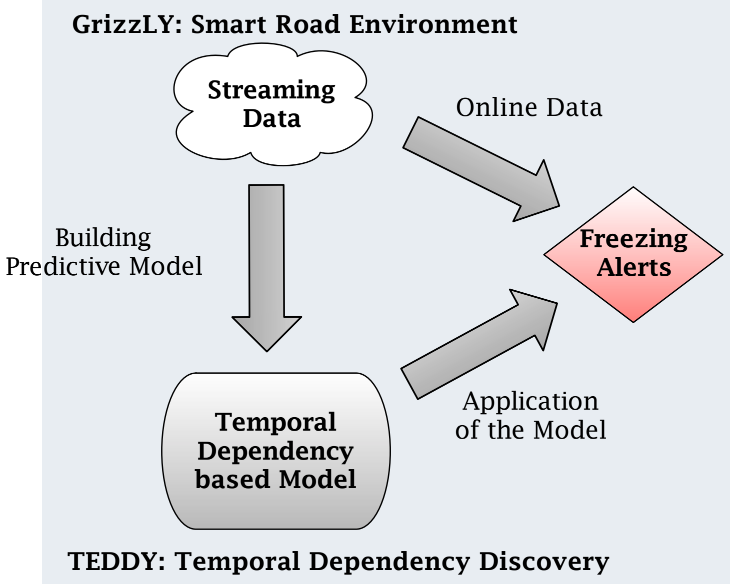
⇝ *Weather forecasting must be done at a smaller scale.*

⇝ Deicing of roads must be organized wisely in order to limit its negative environmental, technical and health impacts.

GRIZZLY and TEDDY System

Weather forecasting at small spatial and temporal scales for the Lyon urban area (Grand Lyon, France).

Overview



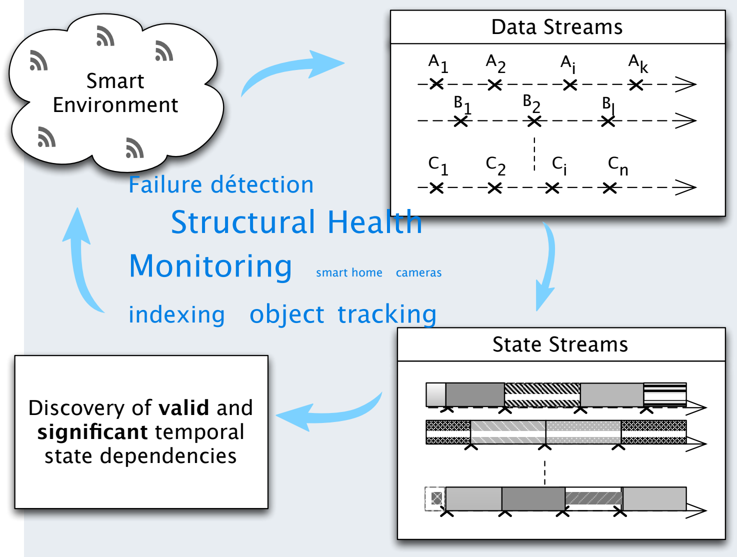
Smart Road Sensor Network

- Deployment of 8 HiKoB wireless sensors to monitor roads
- Ultra low power wireless sensor nodes provide measures every 30s.
- Streaming data are sent to a cloud computing infrastructure using a REST API.
- Real-time information on in-pavement temperature combined with outdoor air temperature and relative humidity.

Temporal Dependency Discovery

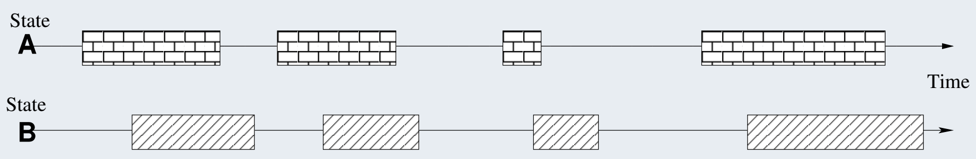
- Extract temporal dependencies between multiple sensor data sources
- Link two types of events if the occurrence of one is repeatedly followed by the appearance of the other in a certain time interval.
- Robust dependencies to the temporal variability of events that identifies the time intervals during which the events are dependent.

TEDDY in a Nutshell



TEDDY Data Formatting

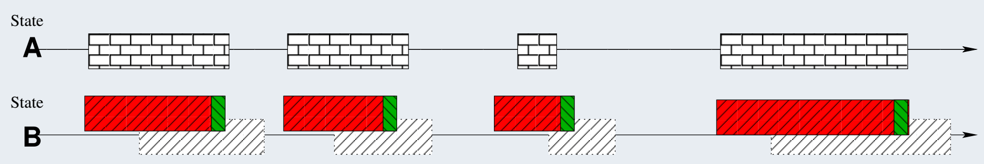
- Discretization of numerical sensor measures to get the stream state set.
- Stream states of a geographical site are combined to form a *site state*, *e.g.*, when the air temperature is negative and the road temperature below the frost point value, the site is in *freezing state*.



Rule Evaluation

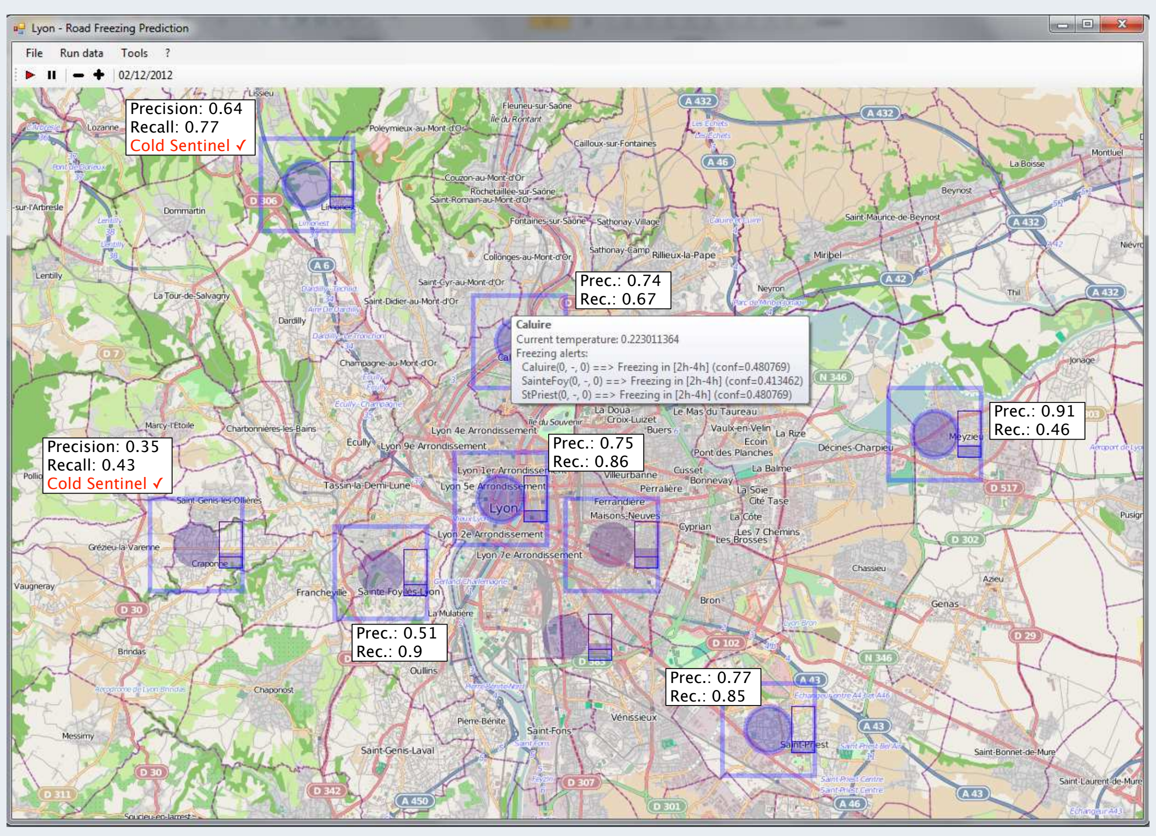
$$\mathbf{len}(A \cap B) = \sum_{i,j} \mathbf{len}([a_i, a_{i+1}[\cap [b_j, b_{j+1}[)$$

Finding the best intervals $[x, y]$ such that $x \leq y \leq 0$, $B^{[x,y]} = \{[b_j + x, b_{j+1} + y[\}$



$$\mathbf{confidence}(A \xrightarrow{[x,y]} B) = \frac{\mathbf{len}(A \cap B^{[x,y]})}{\mathbf{len}(A)} \geq f(\chi^2)$$

Freezing Alert Triggering Tool



First attempt to apply data mining technique to micro-scale meteorology:

- TEDDY is used to provide a two-hours prediction model that makes possible to prognosticate a freezing condition period at least two hours ahead its occurrence.
- This model triggers freezing alerts in a more accurate way than classical weather forecasting does.
- The minimum time between two dependent states is configurable.
- It highlights *trajectories* of freezing alerts: useful to organize and optimize the deicing operations.
- Our model is also useful to place new deployment site.

Such an approach can be used in other contexts (e.g., structural health monitoring).

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