A model to perform knowledge-based abstraction over multiple signals

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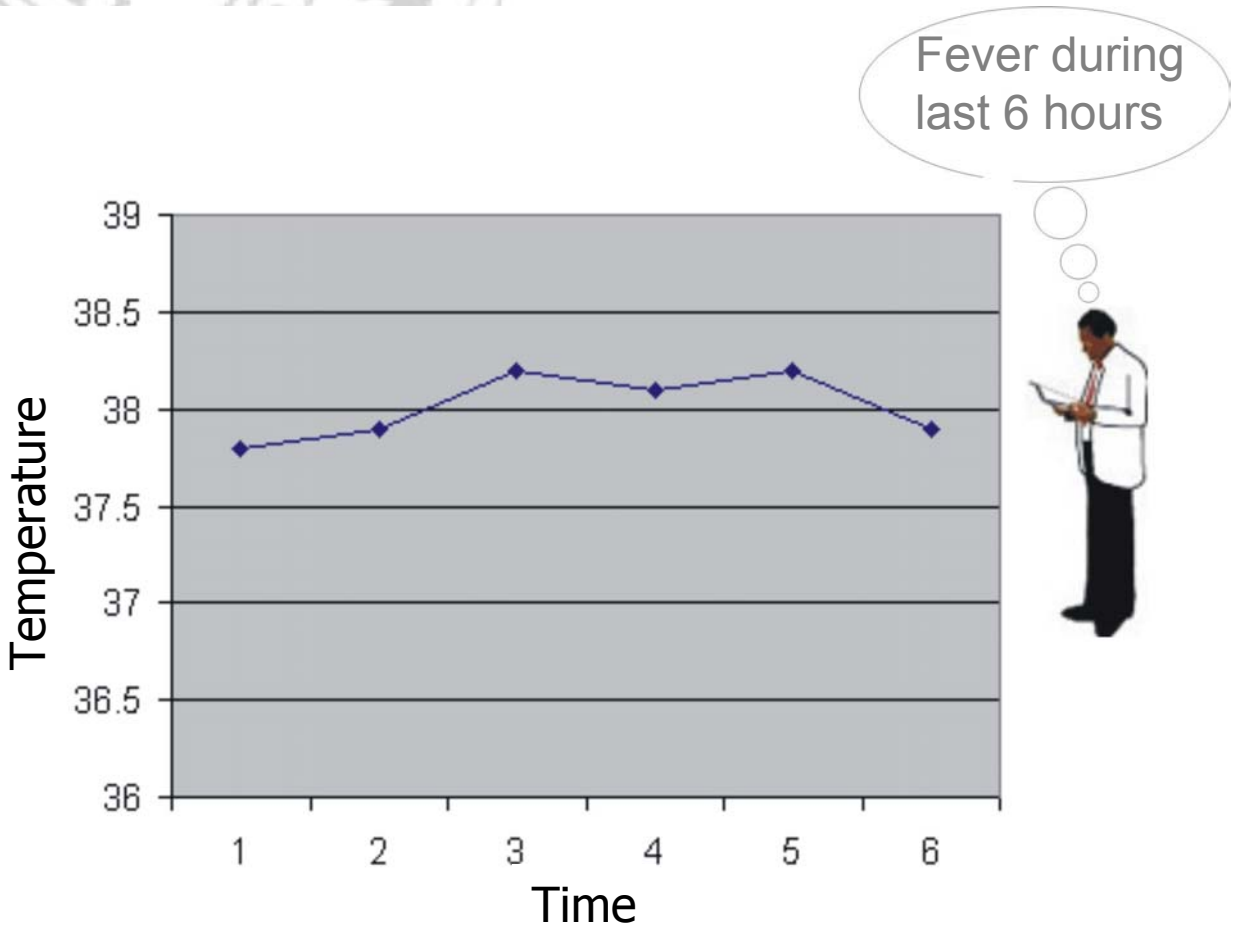
TIME-ICTL 2003

Presentation

- The problem: automation of temporal abstraction
- Prior definitions
- The Multivariable Fuzzy Temporal Profile (MFTP) model
- Matching
- Application: mobile robotics
- Conclusions and future work

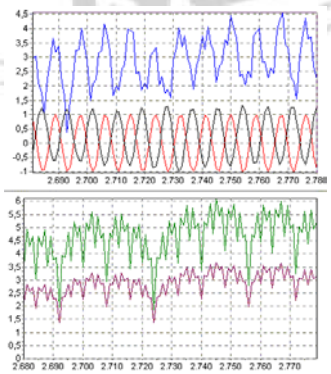
The problem

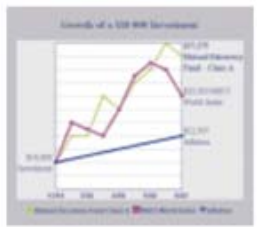
- Humans perform abstraction over the data we must reason over.

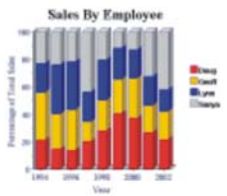


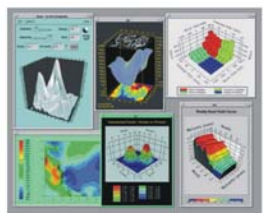
The problem

- Proliferation of electronic measuring devices and improvements in communication processes increases the amount of allowable data:
  - Patient supervision (ICU)
  - Robotics
  - Control of industrial processes



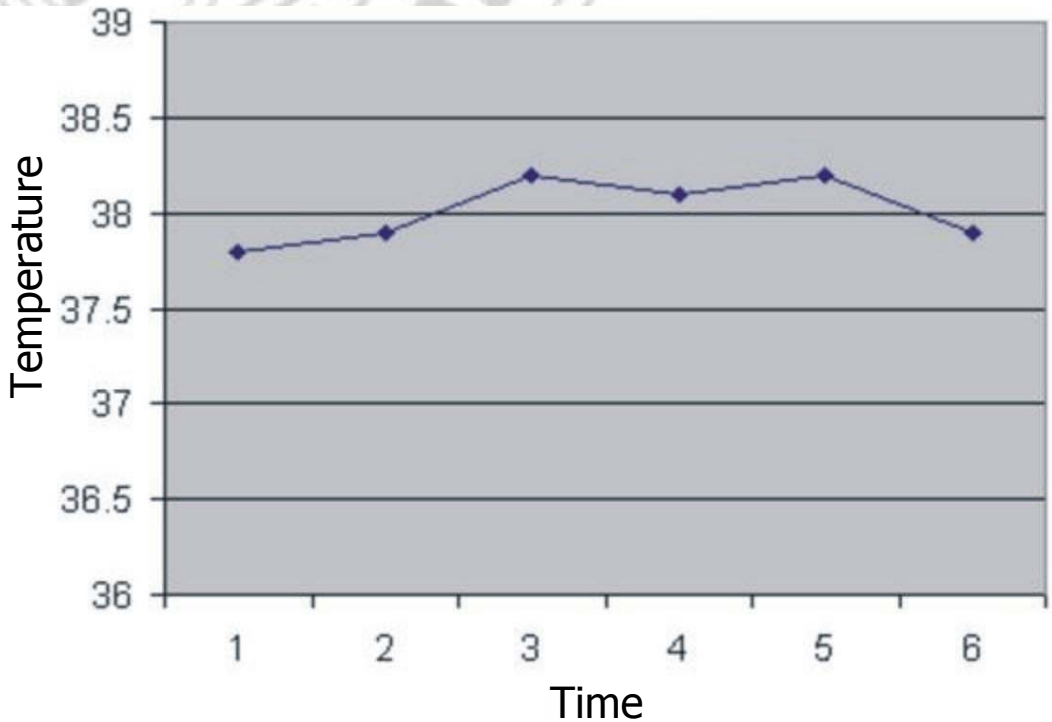






The problem

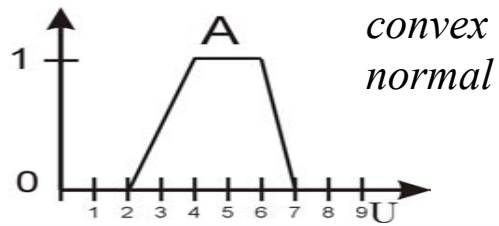
- The solution to the data overload problem requires an automation of data abstraction process.



Prior definitions

- **Fuzzy number A**

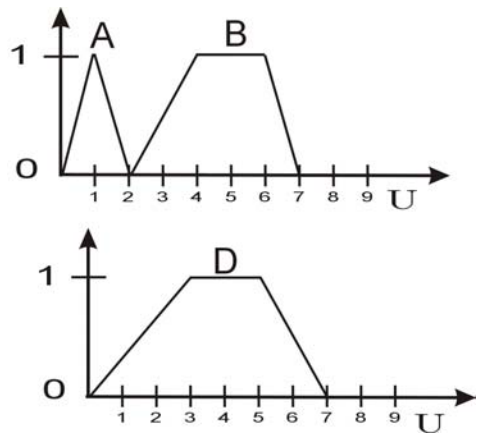
  (τ: Fuzzy Instant)



- **Fuzzy increment D**

  (τ: Fuzzy temporal extension or fuzzy duration)

$$\pi_D(i) = \max_{i=t-s} \min\{\pi_A(t), \pi_B(s)\}$$



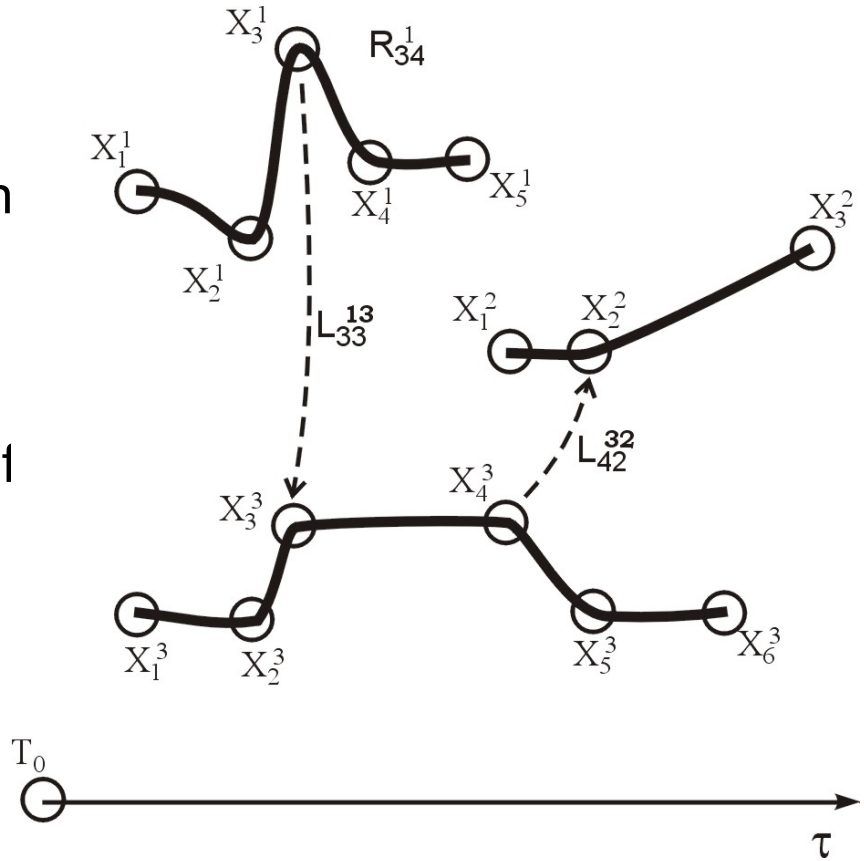
- **Fuzzy interval $I_{(ABD)}$**

  (τ: Fuzzy temporal interval)

$$\pi_{I_{(A,B,D)}}(t_a, t_b) = \min\{\pi_A(t_a), \pi_B(t_b), \pi_D(t_a - t_b)\}$$

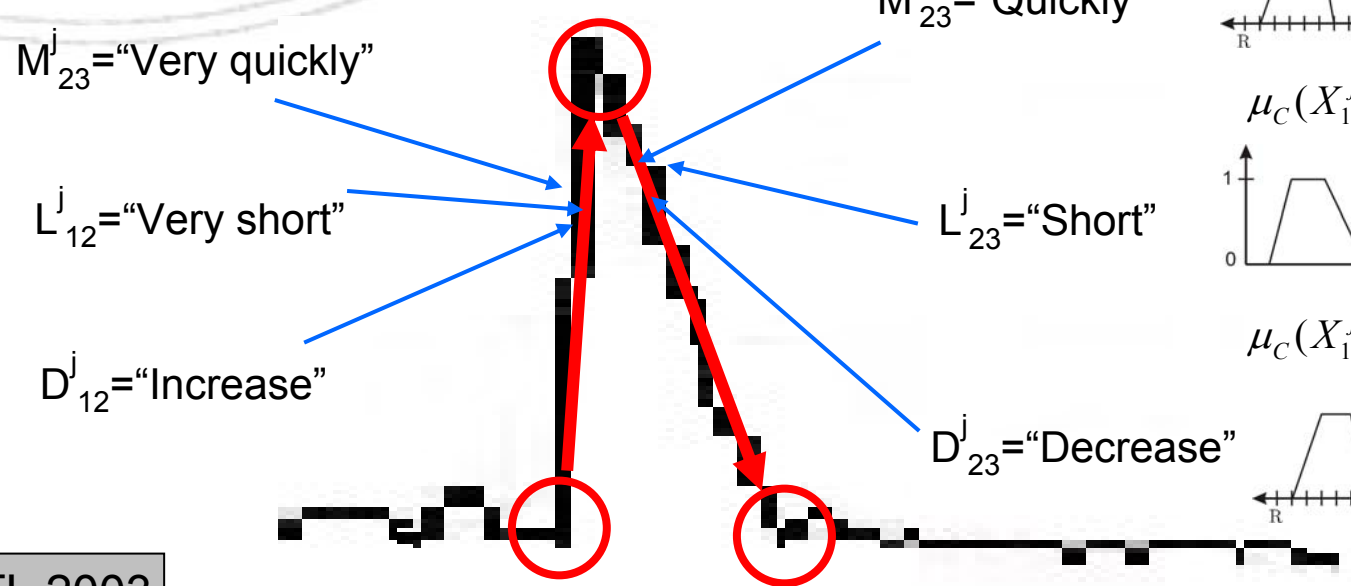
MFTP model

- Allows the projection onto a computational model of the expert knowledge about a pattern **M** defined over the temporal evolution $P = \{P^1, \ldots, P^n\}$ of a system.
- Enables the organization of information into multiple levels of abstraction.
- Based on CSP formalism and on the fuzzy set theory.

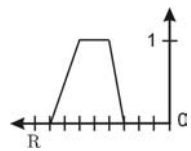


FTP model

- A **Fuzzy Temporal Profile** $N^j = \{X^j, R^j\}$ is a finite set of
  - significant points $X^j = (X_0^j, X_1^j, \ldots, X_{n^j}^j)$; $X_i^j = < T_i^j , U_i^j >$
  - and fuzzy constraints $R^j = (R_0^j, R_1^j, \ldots, R_g^j)$ between them.



$$\mu_C(X_1^j, X_2^j) \equiv \pi_{12}^{M^j}(m)$$

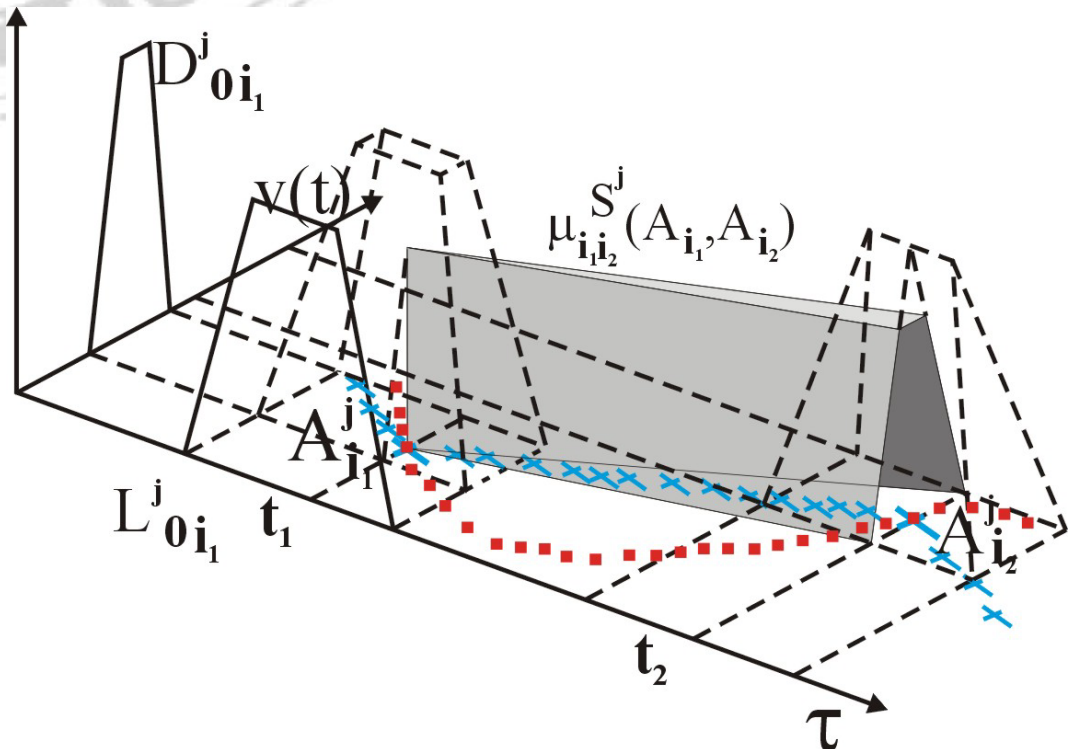


$$\mu_C(X_1^j, X_2^j) \equiv \pi_{12}^{L^j}(l)$$

$$\mu_C(X_1^j, X_2^j) \equiv \pi_{12}^{D^j}(d)$$

FTP model

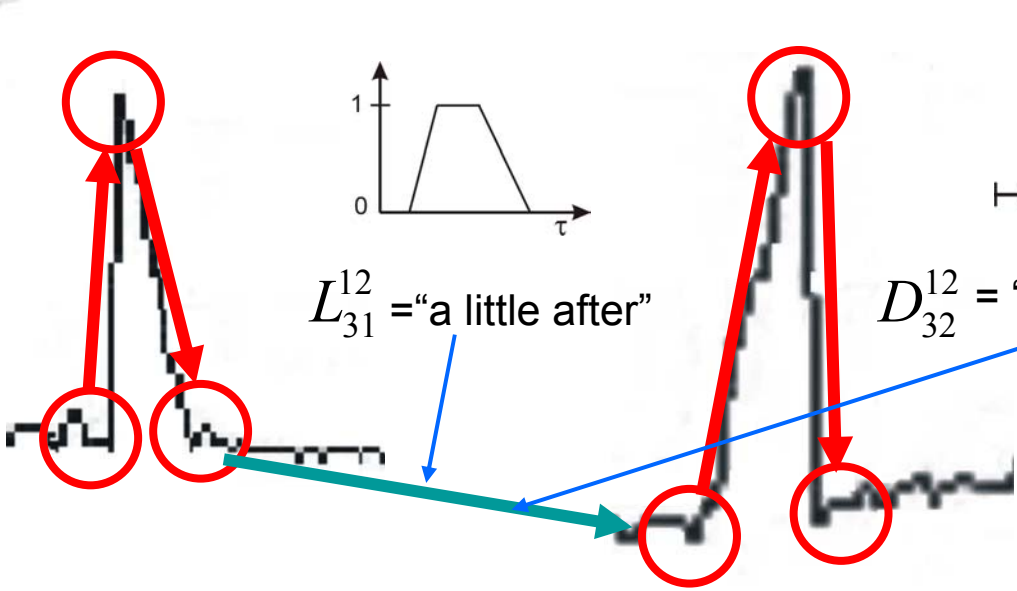
- Fuzzy sets allow the modelling the vagueness and fuzziness characteristics of natural knowledge.
- A language that enables the projection of knowledge into possibility distributions has been developed [Félix, 1999].
- The FTP model also can constrain the evolution of the parameter P^j between each pair of significant points.
- We have also worked on the projection of fuzzy quantifiers on the constraints [Barro, 2002]



MFTP model

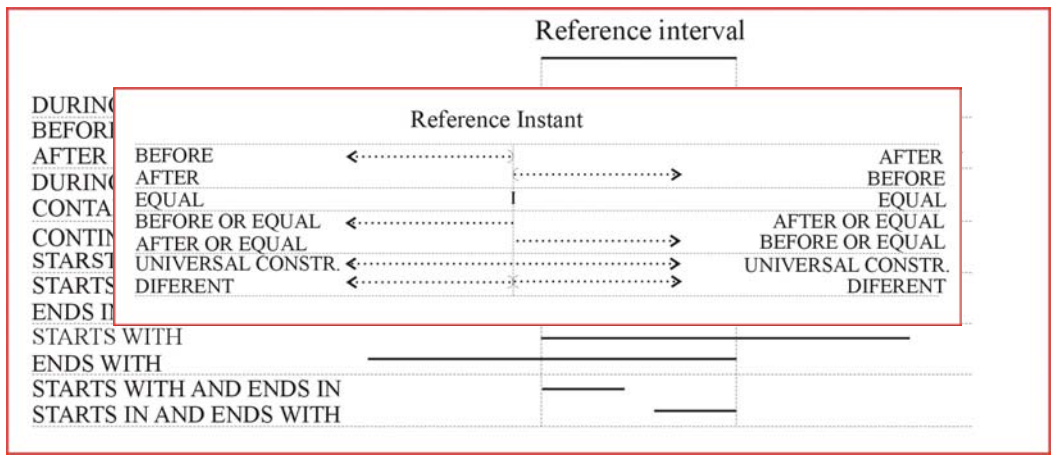
- Extends FTP model enabling constraints between significant points defined over different parameters.
- **Multivariable Fuzzy Temporal Profile** $M = \{X^M, R^M\}$ is defined as a finite set of:
  - significant points $X^M = \{X_0, X_1, \ldots, X_n\}$
  - fuzzy constraints $R^M = \{R_0, R_1, \ldots, R_n\}$ between them

$$\mu_C(X_3^1, X_1^2) \equiv \pi_{31}^{L^{12}}(l) \qquad \mu_C(X_3^1, X_1^2) \equiv \pi_{31}^{D^{12}}(d)$$



Qualitative temporal relations

- We have placed special emphasis on the representation of the temporal disposition of the findings which make up the pattern M. The MFTP model is able to represent qualitative relations:
  - Between instants
  - Between instants and intervals
  - Between intervals



Matching

- The ultimate aim of the MFTP model is to perform matching of the pattern M over the temporal evolution P of the system.

- A **solution** A of a MFTP M is a set of assignments $A = \{A_0, A_1, \ldots, A_n\}$, where $A_1 = (v^j_{[m]}, t^j_{[m]}), (v^j_{[m]}, t^j_{[m]}) \in P^j$, satisfying the set of constraints R^M.

$$(\pi^{R_i}(A^{R_i}) > 0, \forall i)$$

- The degree of satisfaction of a solution A is given by:

$$\pi^M(A) = \min_{R_k \in R^M} \{\pi^{R_k}(A^{R_k})\}$$

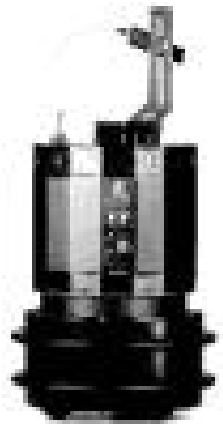
Matching

- We employ a search tree procedure to discard futile assignments: we seek local solutions and then try to extend them to global solutions.
- The problem, in the general case, is NP-complete.
- In the search we employ a non-binary extension of FC: nFC0 [Bessiere, 2002].
- Further heuristics can be employed: prioritizing uncommon events in detections, MVR, knowledge from the domain application…

Matching

- Matching is carried out in two stages in our current implementation:
  - First searching for FTPs that make up the MFTP.
  - Then seeking for the MFTP over the previously found FTP.
- Advantages:
  - More efficient search.
  - Allows explanations to be given on the matching.
  - More suitable for a multiagent implementation.
- Disadvantage
  - Cannot guarantee finding a optimal global solution, even a global solution.

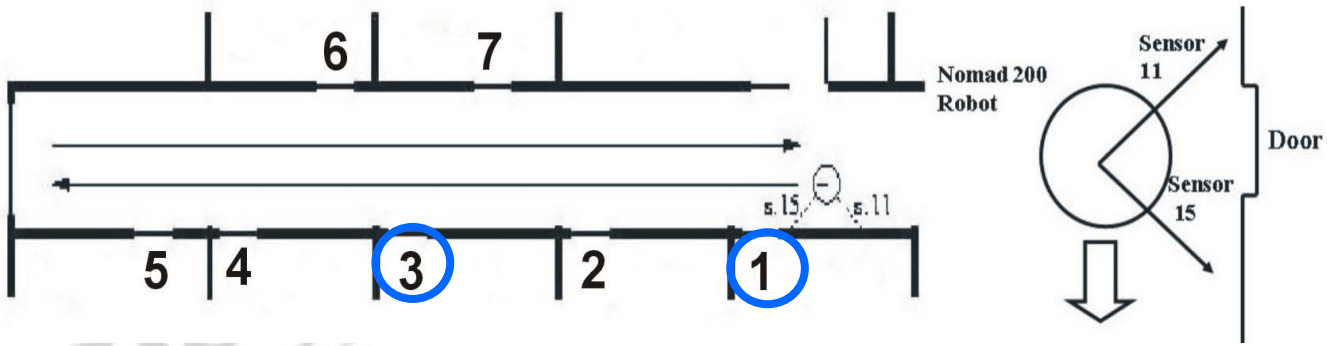
Application: mobile robotics

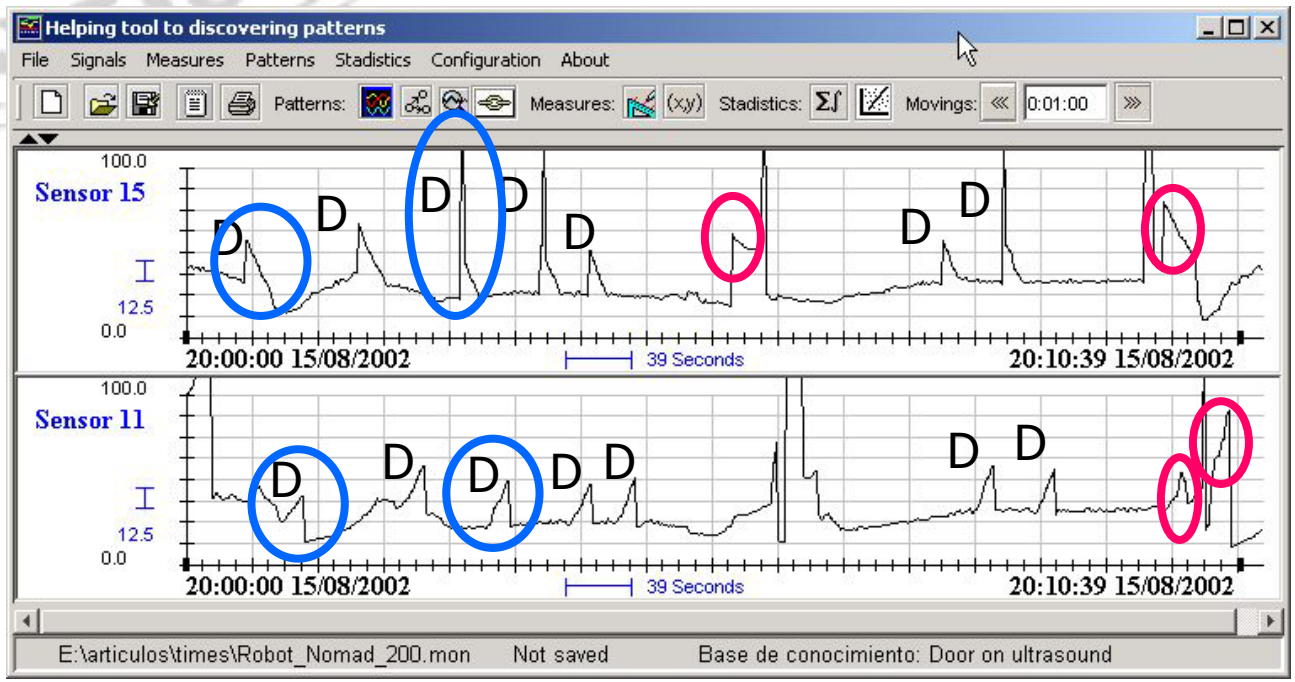


- Sonar and laser sensors of mobile robots measure the distance from a robot to an obstacle.
- Route planning and map buiding requires information about the doors, corridors, corners… of the environment.
- An abstraction must be done over sensors signals to tackle these tasks.
- We will show how MFTP model can do this abstraction.

Application: mobile robotics

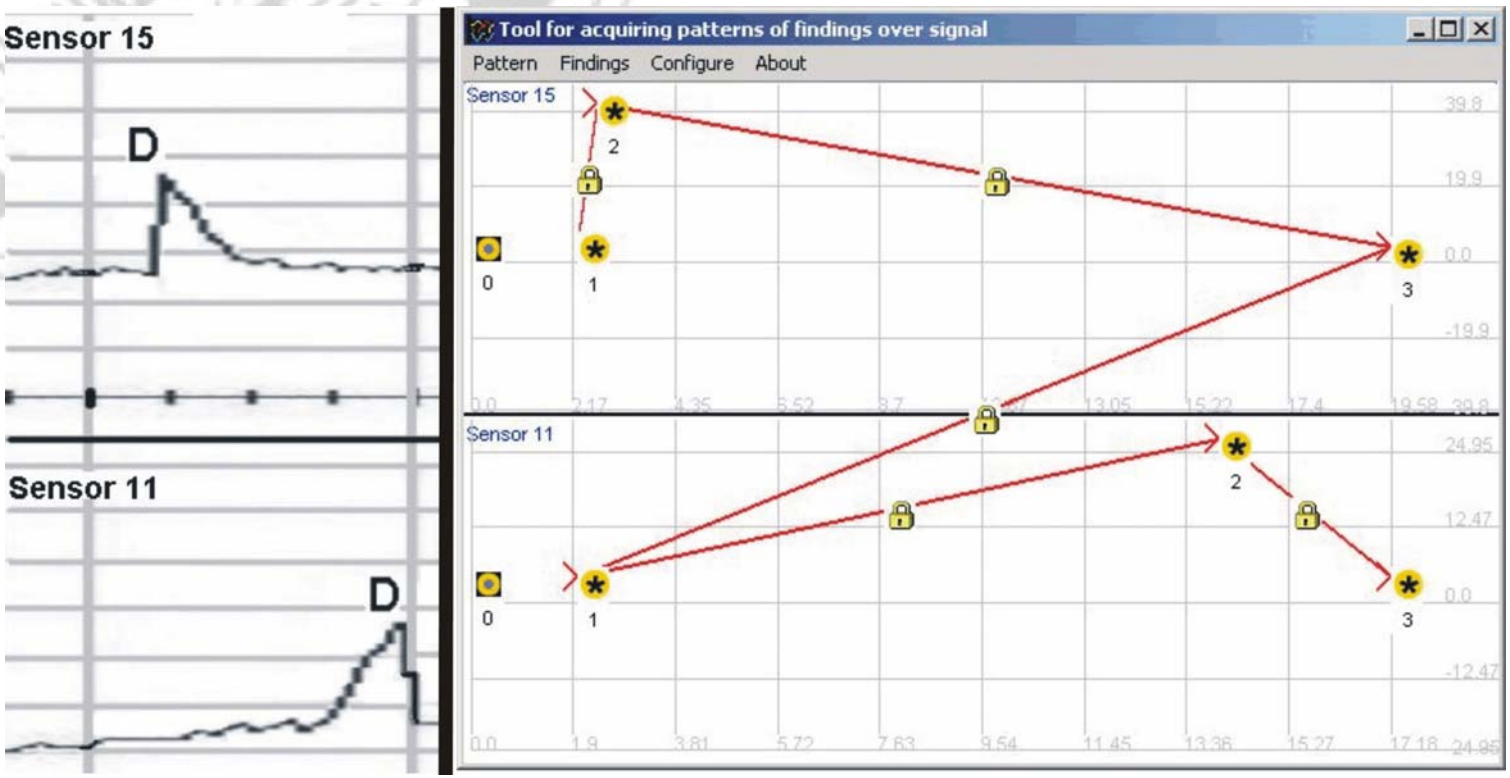
- Sonar sensors employed in the detection





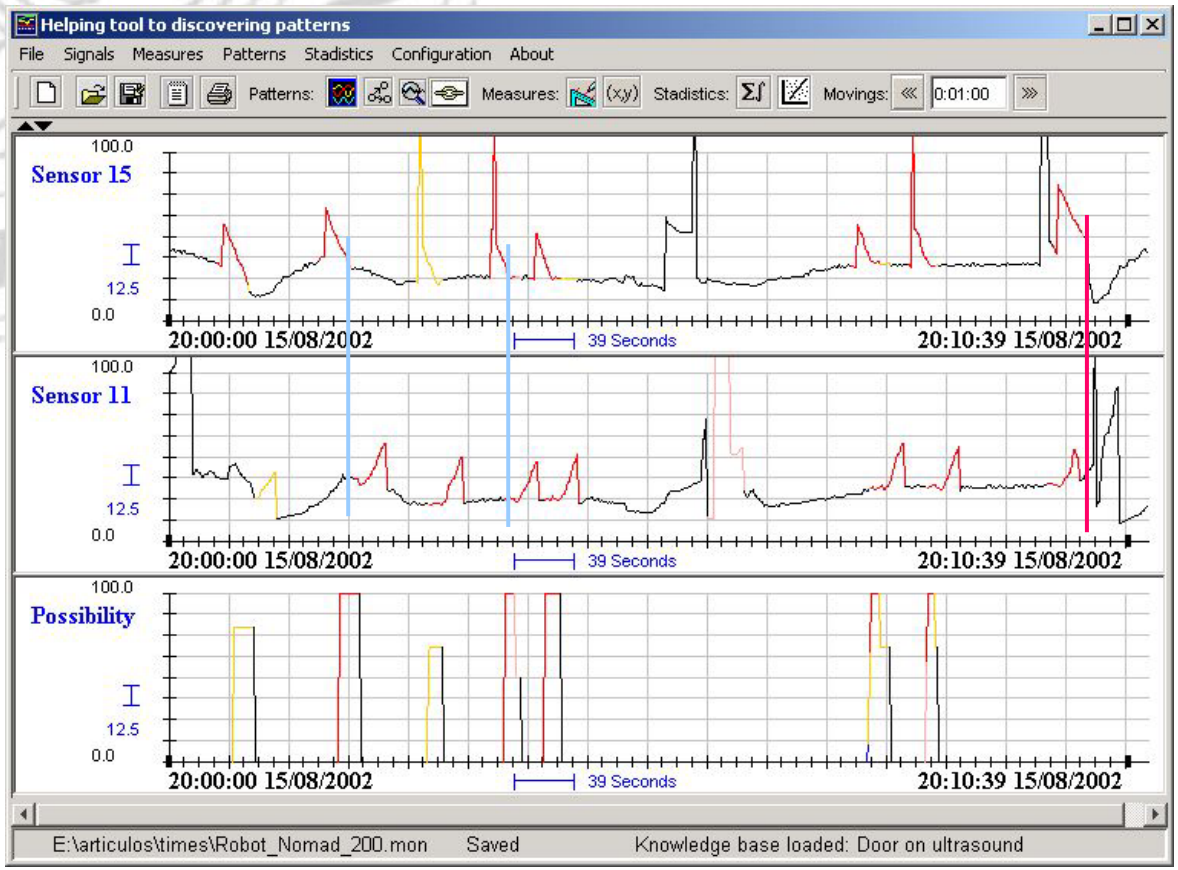
Application: mobile robotics

- Editing of the knowledge base on the **Tool for the Automatic Acquisition and Recognition of Multivariable Patterns**



Application: mobile robotics

- 5 of 7 door detected with poss. 1; 2 with poss. ~0.7
- A trajectory of ~3 min processed in ~ 30 sec



Conclusions

- The MFTP model allows the projection of expert knowledge about a pattern on a computable model and the automatic detection of this pattern.
- The MFTP model can be employed to automate abstraction tasks.
- We present an example of automatic abstraction with the MFTP model: landmark detection in mobile robotics.

Future Work

- Construct a general framework for temporal abstraction where fuzzy constraint networks allow the integration of multiple abstraction techniques.
- Study the problem of the consistency of the MFTP: due to redundancy in expert descriptions there may be inconsistent information.
- Construct a module for landmark detection and integrate it within an architecture.