MFTP: a model to represent hierarchies of abstraction defined over multiples parameters.

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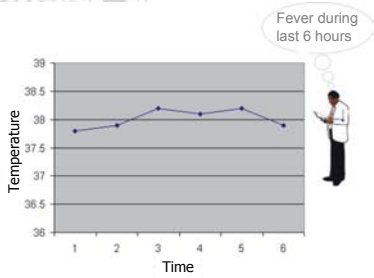
SPAIN

Presentation

- Automation of temporal data abstraction
- A practical example
- Signal abstraction: MFTP model
- Pattern detection
- Applications of MFTP model
- Conclusions and future work

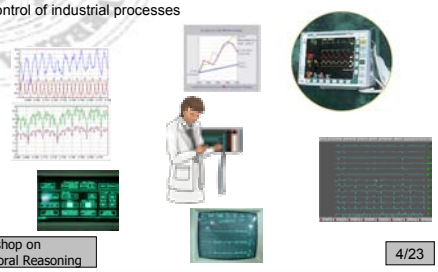
Abstraction

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



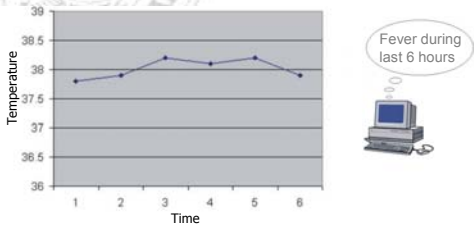
The problem

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



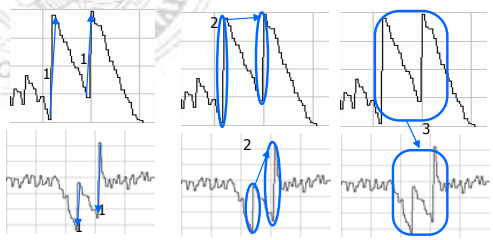
The solution

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



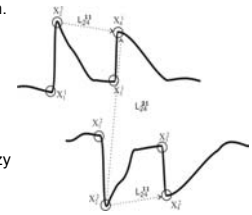
Practical example

- Real pattern from the mobile robotic domain: *double leaf door pattern.*



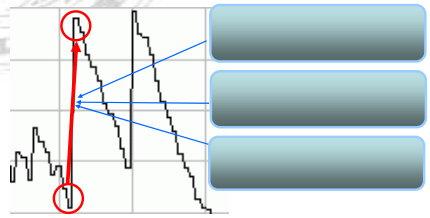
Signal modelling

- An MFTP describes a pattern **M** defined over a set of parameters $P = \{P^1, \ldots, P^n\}$ arising from the temporal evolution of a system.
- Enables the organization of information into multiple levels of abstraction.
- Based on CSP formalism and on the fuzzy set theory.
- MFTP model generalizes Fuzzy Temporal Profile model.
  - FTP model represents morphological patterns defined over a single parameter.



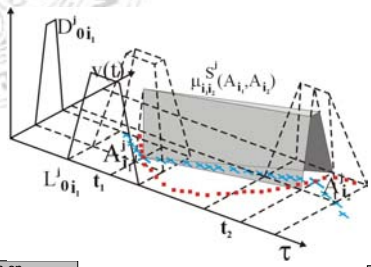
FTP model

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



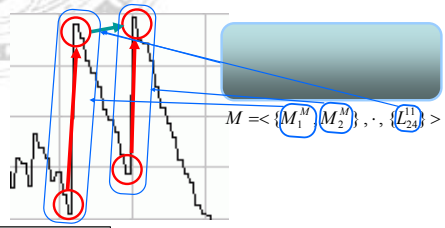
FTP model

- The FTP model also allows to constrain the evolution of the parameter P^j between each pair of significant points.



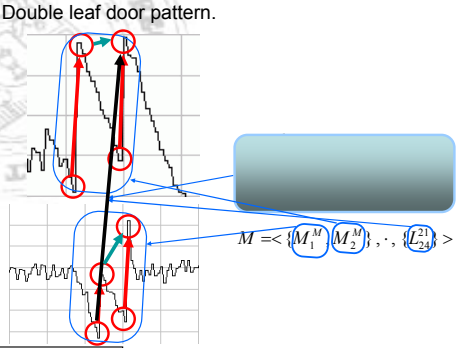
MFTP model

- **Multivariable Fuzzy Temporal Profile** $M = < W^M, X^M, R^M >$ is defined as a finite set of:
  - MFTPs $W^M = \{M_1^M, \ldots, M_s^M\}$
  - significant points $X^M = \{X_1^j, \ldots, X_n^k\}$
  - fuzzy constraints $R^M = \{R_1, \ldots, R_t\}$ between W^M and X^M.



MFTP model

- Double leaf door pattern.



Hierarchical structure

- The hierarchical structure of MFTP model endows it with:
  - Modularity: one MFTP can be composed by several subMFTPs, and at the same time belong to several MFTPs.
  - Efficiency in the matching stage, regarding the matching of the MFTP as a whole.
- Usually $M = \{W^M, \cdot, R^M\}$,and for any subMFTP $M_o = \{\cdot, X^{M_o}, R^{M_o}\}$.
  - Thus the pattern is made up of a set of morphologies defined over different parameters, and a set of relations between them.

Pattern recognition

- The ultimate aim of the MFTP model is the recognition 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 $A_i = (v_{[m]}, t_{[m]}), (v_{[m]}, t_{[m]}) \in P$, satisfying the constraints that make up M.
- The degree of satisfaction of a solution A is given by:

$$\pi^M(A) = \min\{\min_{M_k^M \in W^M}\{\pi^{M_k^M}(A^{M_k^M})\}, \min_{R_k \in R^M}\{\pi^{R_k}(A^{R_k})\}\}$$

The algorithm

- Matching is carried out following the hierarchy of abstraction described in the pattern.
  - First of all the subMFTPs that make up the MFTP are searched for, and then we seek for the MFTP over the previously found subMFTPs. The search starts with those subMFTPs which contain no subMFTPs.
- We employ for the search a non binary extension of Forward Checking: nFC0 [Bessiere, 2002].
  - MFTPs usually are associated with non-dense hypergraphs.

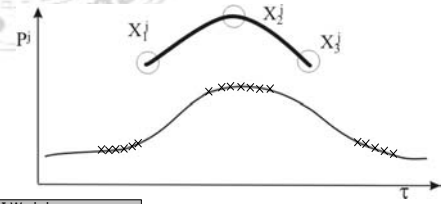
Complexity

- The problem is, in the general case, NP complete.
- However MFTP's hierarchical structure alleviates the complexity of the matching task, allowing to easily achieve real-time performance for the real patterns studied.
- Lets consider the more common hierarchy: an MFTP made by m morphological subMFTP, each of them of n^h significant points:

Hierarchical Matching >> Matching in a single stage

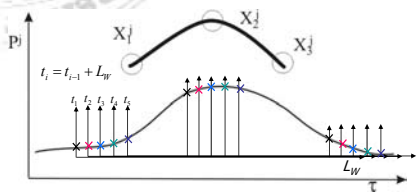
Huge variables domain

- The huge number of possible solutions for each subMFTP counterbalance the benefits of the hierarchical matching.



A highly efficient heuristics

- We search for one solution inside a temporal window of length L_W which is been displaced over the temporal evolution of the parameter.
  - We try to obtain "sampling" of the pattern.



A highly efficient heuristics

- The heuristics sacrifices the completeness of the algorithm.
- However in the practice works pretty fine
  - It never has missed a pattern in real registers when an appropriate L_W is employed. Seldom the global degree of compatibility of the global pattern is inferior to the optimal one.
- Further heuristics can be employed: prioritizing uncommon events in detections, Minimum Value Remaining (MVR), exploiting knowledge from the domain…

Patient supervision

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MFTP model
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Future work

- Employed to generate intelligent alarms based on physicians knowledge.
- The Tool foR aqCquiring and disCovering pattErns (TRACE) [A. Otero et. al, FUSION 2004] has been developed to allow physicians to:
  - Project their knowledge about real patterns onto MFTP model.
  - Validate and refine the MFTPs.
  - Generate pattern recognition algorithms.

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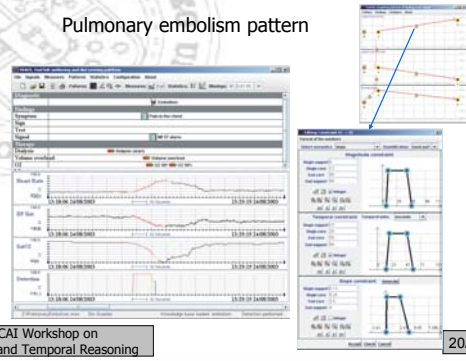
Pulmonary embolism pattern



Mobile robotics

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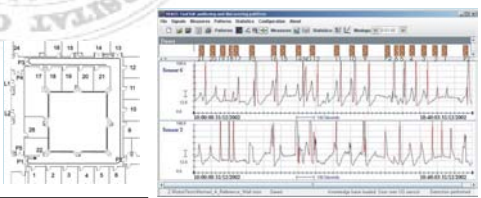
- Applied to landmark detection over signals from the sensors of mobile robots.
  - A system for identifying doors, corners, ends of corridors and columns from ultrasound signals has been developed. [A. Otero et. al, IPMU 2004]



Conclusions

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- The MFTP model allows the projection of expert knowledge about a pattern on a computable model, capturing explicitly the hierarchy of abstraction levels inherent to the pattern.
- The MFTP model can be employed to automate abstraction tasks, and to reason over the temporal evolution of a system.
- Despite its theoretically high complexity the heuristics developed allow to easily obtain real-time performance for the real patterns studied.

Future Work

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- 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.