# I-TUTOR Maps

## Exploring the theoretical background

Arianna Pipitone, Vincenzo Cannella, and *Roberto Pirrone*

Department of Chemical, Mechanical, Computer,
and Mechanical Engineering
(DICGIM)

UNIVERSITÀ
DEGLI STUDI
DI PALERMO

# I-TUTOR overview

- Intelligent Tutoring for Lifelong Learning
  - An *AI enriched* VLE, which supports
    - Monitoring
    - Instructional design
    - Self-regulation in students

# I-TUTOR overview – The plugin

- I-TUTOR plugin functionalities:
  - Maps
  - Monitoring
  - Profiling
  - Alerting

- I-TUTOR supports multilingual Moodle courses.

# I-TUTOR overview - Users

- Three kinds of users with different needs
  - Instructional designer
  - Tutor
  - Student

# Users - Tutor

- Monitoring students
  - Single student
  - Entire class

- Student and class activities
  - Time spent on studying
  - Contents produced by the student/class
  - Social activities of the student/class

# Users - Tutor

## Monitoring (students vs time)

| | *At a given time* | *Over a period* |
|---|---|---|
| *Single student* | **Disaggregate data analysis** | **Disaggregate diachronic data analisys** |
| *Entire course* | **Aggregate synchronic data analysis** | **Aggregate diachronic data analysis** |

# Users - Student

- Self-monitoring
  - Through time
    - advances  throughout the course
  - Proper access to contents
    - Referencing materials to the topics of the course

- Self-regulation

# Users – Instructional designer

- Knowledge Domain Authoring
- Course Authoring
  - Overview of the contents of a course
  - Topics of the course
  - Relationships between topics
    - Semantic similarity
    - Pre-requisite (Timing of the contents)

# Relevant Processes in I-TUTOR

- Authoring
    - Domain representation
    - Semantic tecnologies
    - Visualization
- Information Retrieval
    - Navigation
    - Accessing materials
    - Visualization
    - Semantic technologies
- (Self-)assessment
    - Visualization

# Domain representation

- How to represent knowledge about a domain
  - A set of facts and events
- Explicit representation
  - Ontologies
  - Conceptual Maps (hypertext…)
- Implicit representation through verbose texts
  - Definitions
  - Learning materials

# Explicit Domain Representation

- Pros
  - Based on formal description of domain facts and events

- Cons
  - Requires meta knowledge about the kind of representation (ontologies, ERD, general taxonomies)
  - High complexity

# Implicit Domain Representation

- Pros
  - Direct use of texts
  - Verbose
  - Not structured
  - Easy to implement
  - No technical skills needed
- Cons
  - Needs intensive information analyses techniques

# Information Retrieval and Assessment

- Many facets to be managed:
  - Content
  - Course
  - Student
  - Class
  - Studying Activities
  - Social Activities
- …and relations between above-mentioned facets…

# Semantic Technologies

- Symbolic analysis and linguistic approaches for NLP
  - Semantic parsing
  - Named entity recognition
  - …
- Sub-symbolic analysis
  - Machine learning and statistical evaluation
- Explicit vs Latent Semantic

# Course Visualization

- Overview of the course
  - Topics
  - Semantic relations between topics
    - Similarity
    - Adjacency
    - Overlapping
    - Hierarchy
  - Topics’sequencing

# Content Visualization

- Different kinds of contents
  - Learning materials
  - Contents produced by the students
    - Homeworks
    - Social activities
- Topic-based classification
- Distribution over topics

# Activities Visualization

- Studying activities
    - Amount of documents accessed and/or produced by the user

- Social activities
    - Amount of discussions inside the social media and their relation with course topic

# The Proposed Solution

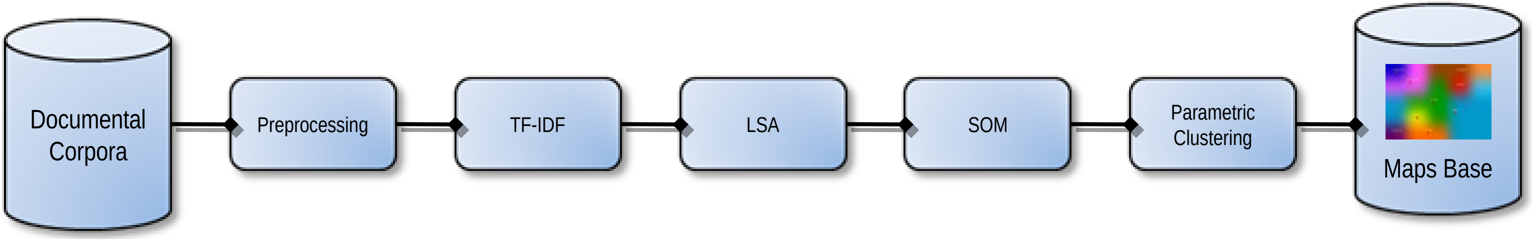
A sub-simbolic statistical method for classifying concepts and didactical documents of a course

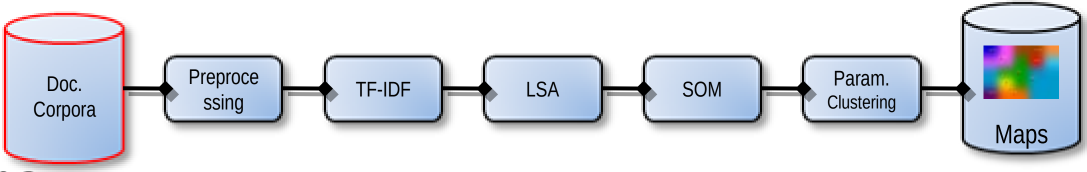
Creation of a semantic space representing the course domain where data analysis can be performed

New documents and/or activities can be *projected* into the space or a new classification can be made

Graphic rendering of the space through a ZUI map

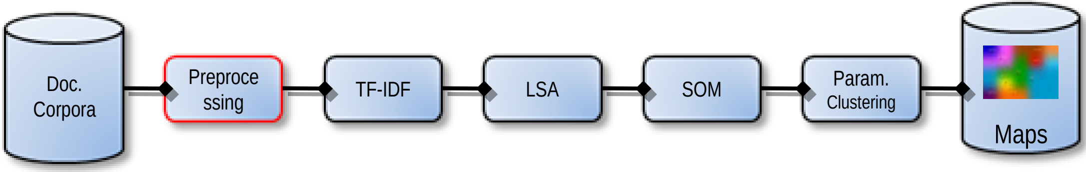
# I-TUTOR Maps pipeline





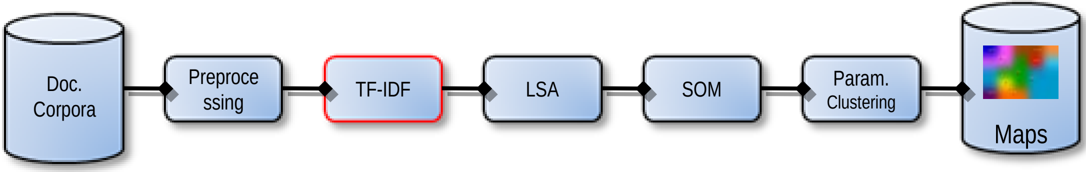

# Documental Corpora

- Weighted keywords
- Hidden database and keywords definition
- Didactical documents
- Teacher learning materials
- Documents by students
  - Social (forum, chat)
  - Didactical (test answers, notes, and so on)




# Preprocessing

- Stemming
- Stop-words removal




# TF-IDF

TF–IDF is a numerical statistic evaluation which reflects how important a word is into a collection of document or corpus.

It is computed through the two numbers:

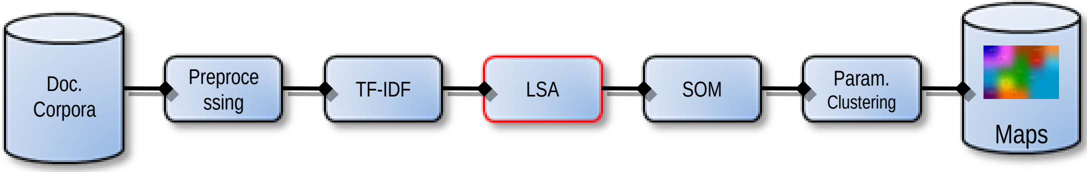
$$\mathrm{tf}_{i,j} = \frac{n_{i,j}}{|d_j|} \qquad \mathrm{idf}_i = \log \frac{|D|}{|\{d : t_i \in d\}|}$$

where $n_{i,j}$ is the number of occurrences of term $t_i$ in the document $d_j$ and $|D|$ is the number of documents.

Finally

$$(\text{tf-idf})_{i,j} = \mathrm{tf}_{i,j} \times \mathrm{idf}_i$$

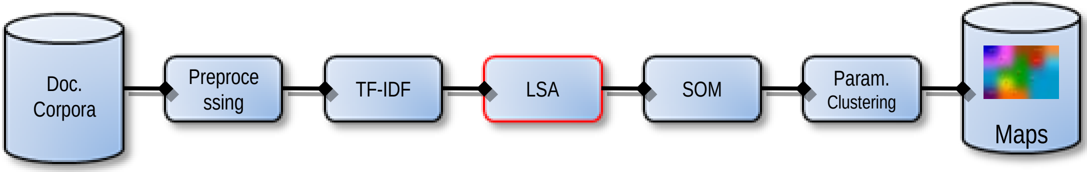
# Latent Semantic Analysis




LSA analyzes relationships between a set of documents and the terms they contain

LSA produces a set of concepts related to the documents and terms. LSA assumes that words that are closed in meaning will occur in similar pieces of text.

# *LSA Occurrence Matrix*

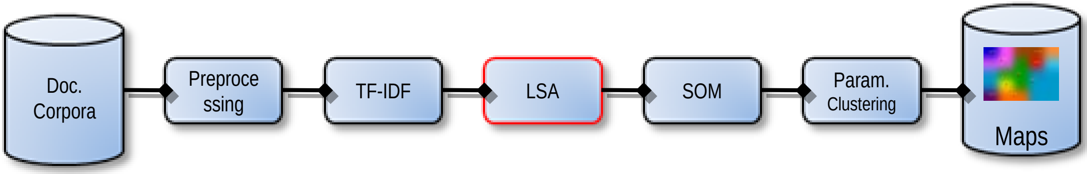



The LSA Occurrence Matrix describes the occurrences of terms in documents

It is a sparse matrix whose rows correspond to terms and whose columns correspond to documents;

We use TF-IDF for weighting the elements of the matrix.

$$\mathbf{t}_i^T \rightarrow \begin{bmatrix} x_{1,1} & \overset{\displaystyle \mathbf{d}_j \atop \downarrow}{\dots} & x_{1,n} \\ \vdots & \ddots & \vdots \\ x_{m,1} & \dots & x_{m,n} \end{bmatrix}$$

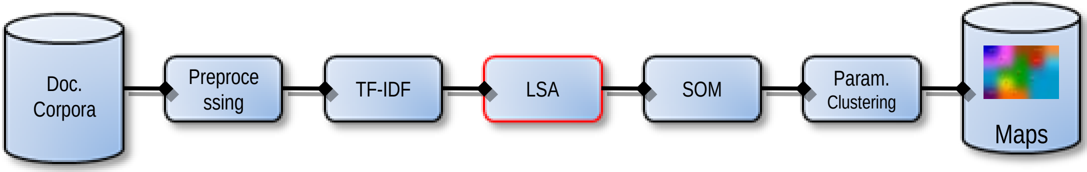



## *LSA Decomposition*

For reducing LSA matrix dimension the Singular Value Decomposition (SVD) is applied.

$$\begin{array}{c} X \\ (\mathbf{d}_j) \\ \downarrow \end{array} \qquad\qquad\qquad U \qquad\qquad \Sigma \qquad\qquad \begin{array}{c} V^T \\ (\hat{\mathbf{d}}_j) \\ \downarrow \end{array}$$

$$(\mathbf{t}_i^T) \rightarrow \begin{bmatrix} x_{1,1} & \dots & x_{1,n} \\ \vdots & \ddots & \vdots \\ x_{m,1} & \dots & x_{m,n} \end{bmatrix} = (\hat{\mathbf{t}}_i^T) \rightarrow \begin{bmatrix} \begin{bmatrix} \mathbf{u}_1 \end{bmatrix} \dots \begin{bmatrix} \mathbf{u}_l \end{bmatrix} \end{bmatrix} \cdot \begin{bmatrix} \sigma_1 & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & \sigma_l \end{bmatrix} \cdot \begin{bmatrix} \begin{bmatrix} & \mathbf{v}_1 & \end{bmatrix} \\ \vdots \\ \begin{bmatrix} & \mathbf{v}_l & \end{bmatrix} \end{bmatrix}$$

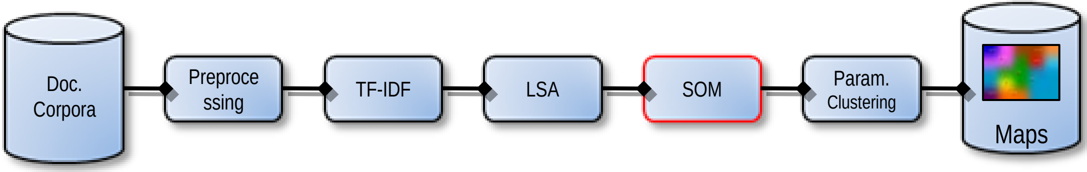



## *LSA Spaces*

Document’s space

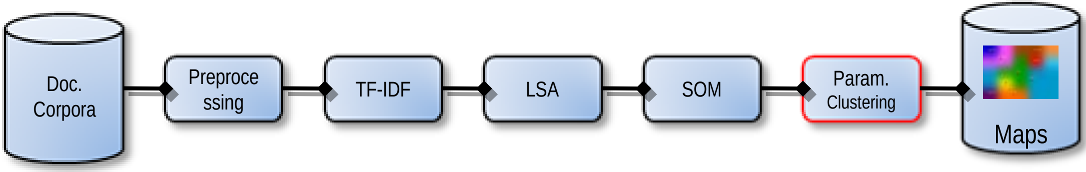
Concept’s space

I-TUTOR Conceptual and Activity spaces




# Self-Organizing Maps

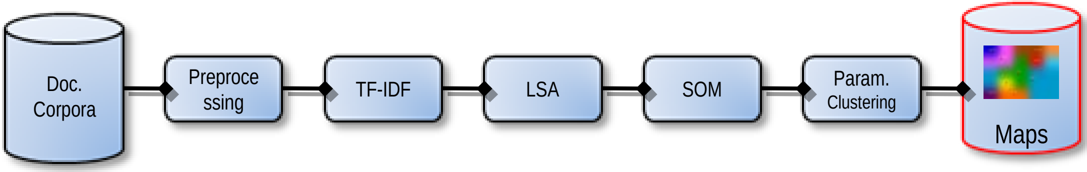
- A type of artificial neural network
  - it is trained through unsupervised learning for producing a map
  - map is a low-dimensional (typically 2D) representation of the input space
- Two operating modes
  - Training: builds the map using input examples
  - Mapping: automatically classifies a new input vector
- Vectors from the semantic space are placed into the map by finding the node with the closest weight vector (in the euclidean sense).




# Clustering

- K-means clustering
- Parametric clustering
  - changing keywords weights

# I-TUTOR Process Pipe
## *Generating maps*




- Multilinguism Problem
- Graphic Communication
- Visual Code

# Interface – Goals and Solutions

| *Goal* | *Solution* |
|---|---|
| **Looking at contents and topics together in one shot** | **Concept map** |
| **Easy to understand** | **Choice of suitable metaphors in the GUI** |
| **Easy to use** | **Zooming User Interface** |
| **Expressive** | **Visual Code** |

# Interface - Concept Map and Metaphor

- *Topics* as ***Concepts of the domain***
- *Topics and Documents* as ***Points in a map***
- *Starry sky* as metaphor for enabling ***quick access to contents***
- *Topology and Metrics* as <u>metaphors</u> to depict the ***Coceptual Space***

# Interface - GUI

- Zooming User Interface
  - Recursive nesting
  - Arbitrary level of zoom
  - Easy to interact
    - Reduced number of actions
      - Click
      - Drag
    - Familiarity (Google Maps, …)

# Interface - Visual Code

| *Graphical element* | *Meaning* |
| --- | --- |
| **Colours code (distinct colours for distinct region)** | **Cluster of documents sharing a common topic** |
| **Brightness** | **Number of documents in a cluster** |
| **Shapes** | **Markers to locate studied documents** |
| **Size** | **Number of studied documents – Spread of a topic in the course** |
| **Spatial closeness** | **Semantic similarity** |

# Evaluation

- First piloting round for enabling deep technical upgrades
- Second piloting round for making intense evaluation of the maps
  - More than 100 students involved in the courses owned by the partners
- First results are encouraging
  - More than 60% of interviewed people appreciated I-TUTOR as a whole

# Future works

- NLP techniques for processing corpora
  - Topic Categorization (Ontology learning)
  - Symbolic approach
  - Semantic annotation
- NLP techniques for social activities
  - Pattern definition and matching
  - Co-reference resolution
  - Anaphors

# Future works

- Corpora Clustering
  - Sub-symbolic (Hierachical clustering, multi-clustering)
  - Symbolic (faceted classification)

# Future works

- Visualization
  - New metaphors
  - 3D visualization
  - New facets to describe a student
    - Social Interactions (nets, information flows, roles)
    - Complex Behaviours described as combinations of different facets
    - The task at hand