Fuzzy Analogy: A New Approach for Software Cost Estimation

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Summary

- Introduction
- Software Cost Estimation Models
- Estimation by Analogy
- Fuzzy Logic
- Linguistic Quantifiers
- Fuzzy Analogy
- Conclusions and Future Work

Introduction

- Software cost estimation is one of the most critical activities in managing software projects
- Estimation by Analogy is a promising technique to solve the software estimation problem
- Critic : Estimation by Analogy cannot handle categorical data such as ‘very low’, ‘low’, ‘high’....
- However, software projects are always described by categorical rather than numerical data:
  - COCOMO’81: 16 out of 17 attributes are categorical
  - COCOMOII: 22 out of 24
  - Function Points : Evaluation of the complexity for Inputs, Outputs, Files, Inquiries. Evaluation of the TCF

Objective

A new approach for software cost estimation based on reasoning by **Analogy**, **Fuzzy Logic** **and** **Linguistic Quantifier**

Fuzzy Analogy

Software Cost Estimation Models

History

- 1975, Halstead

$$Effort = \frac{m_1 N_2 Log(m_1 + m_2)}{2Sm_2}$$

- 1978, Putnam

$$\mathrm{CT} = (\frac{\mathrm{DSI}}{\mathrm{C}})^{\frac{9}{7}} \mathrm{D}_0^{\frac{4}{7}}$$

- 1981, Boehm, COCOMO

Software Cost Estimation Models

Classification

Algorithmic Models

- **Regression simple/multiple, Interpolation, Bayesian, PCA, etc.**

- **Advantages**
  - Easy to use
  - Easy to develop
- **Critics**
  - They make assumption about the form of the prediction function $Effort = a \times size^{b}$
  - They need to be adjusted or calibrated to local circumstances

Software Cost Estimation Models

- **Classification**
  - **Non-algorithmic Models**
    - **NN, CBR, Rule Induction, Regression Trees**
    - **Advantages**
      - Capabilities to adequately model the complex set of relationship between factors
      - Learning
      - Their behavior is easy to understand
    - **Critics**
      - They are not easy to develop
      - They need software tools to automate their process

Estimation by Analogy

- **Estimation by Analogy is based on the affirmation :**

  Similar software projects have similar costs

- **Estimation by analogy is composed by :**
  - **Characterization of the projects by a set of attributes such as Reliability, Complexity, Analysts competence ...**
  - **Evaluation of the similarity between the candidate project and each project in the database**
  - **Adaptation**

- **Related Works** : Vacninanza, **Sheppered**, Briand, Angelis,...

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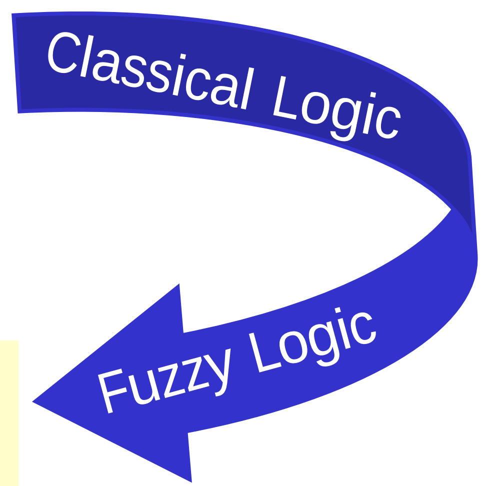
Shepperd et al. (1997)

$$d(P_1,P_2,V) = \frac{1}{\sum_{v_j} d_{v_j}(P_1,P_2)}$$

$$d_{v_j}(P_1,P_2) = \begin{cases} (V_j(P_1) - V_j(P_2))^2 \\ \begin{cases} 0 & \text{si } V_j(P_1) \neq V_j(P_2) \\ 1 & \text{si } V_j(P_1) = V_j(P_2) \end{cases} \end{cases}$$



Imprecise and Uncertain Data

Low, High, Excellent ???

- **Idri and Abran, 7^{th} FT&T, Atlantic City, 2000**

  The equality distance is not precise and can give great difference when estimating effort for two similar software projects described by **Vagueness information**

- **Idri and Abran, 6^{th} MCSEAI, Morocco, 2000**

  We have proposed a set of similarity measures based on fuzzy logic

- **Idri and Abran, 7^{th} IEEE Metrics, London, 2001**

  We have validated by means of an axiomatic approach the proposed similarity measures

- **Idri and Abran, 9^{th} IFSA/20^{th} NAFIPS, Vancouver, 2001**

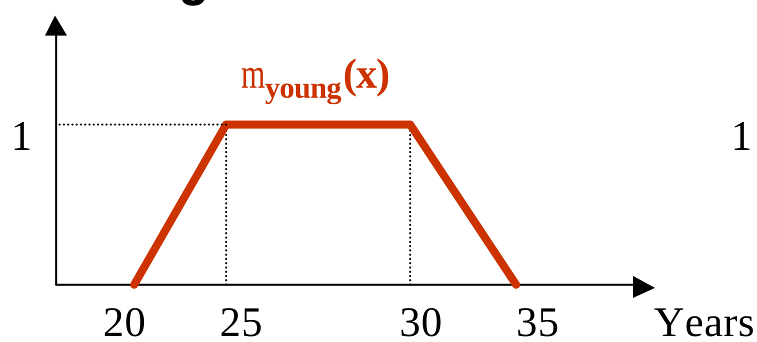
  We have improved the retained measures by using linguistic quantifier guided aggregations

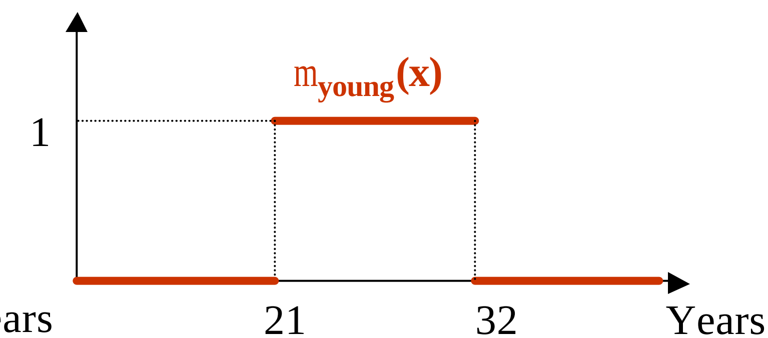
Fuzzy Logic

- **Values between ‘TRUE’ and ‘FALSE’ ?**

  ‘The main motivation of fuzzy logic is the desire to build up a formal, quantitative framework that captures the vagueness of human knowledge via natural languages’ Dubois and Prade 1991

- **1965, Zadeh : Fuzzy Set**
- **1994, Zadeh : Fuzzy Logic = Fuzzy Set Theory**
- **Fuzzy Set: set with a membership function which takes values in the unit interval [0, 1] rather than in the {0, 1} as in the classical logic**





Linguistic quantifiers

- **Human discourse uses a large number of linguistic quantifiers**
- **Zadeh distinguishes between two classes:**
  - Absolute linguistic quantifiers '**approximately 10'**
  - Proportional linguistic quantifiers (**most**, **few**, **at least**, **at most**,...)
- **Yager has distinguished three categories of proportional quantifiers:**
  - RIM quantifiers (**most**, **at least** a ,...)
  - RDM quantifiers (**few**, **at most** a ,...)
  - RUN quantifiers (**about** a)

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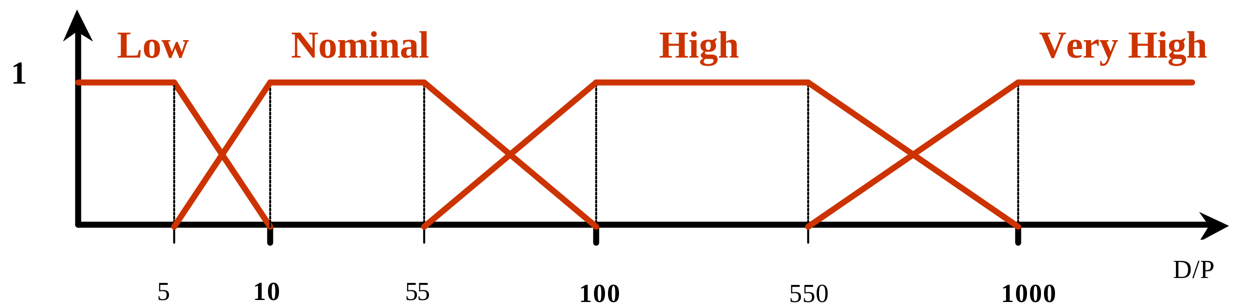
Fuzzy Analogy for Cost Estimation

- **Fuzzy Analogy is a fuzzification of the classical analogy procedure**
- **Fuzzy Analogy is composed of three steps:**
  - Identification of software projects
  - Evaluation of similarity between projects
  - Adaptation
- **Identification Step:**
  - The aim is to describe the software projects by a set of attributes that are:
    - **Relevant**
    - **Independent**
    - **Comprehensive**
    - **Operational**

- **Each selected attribute is measured either by numerical or categorical data**

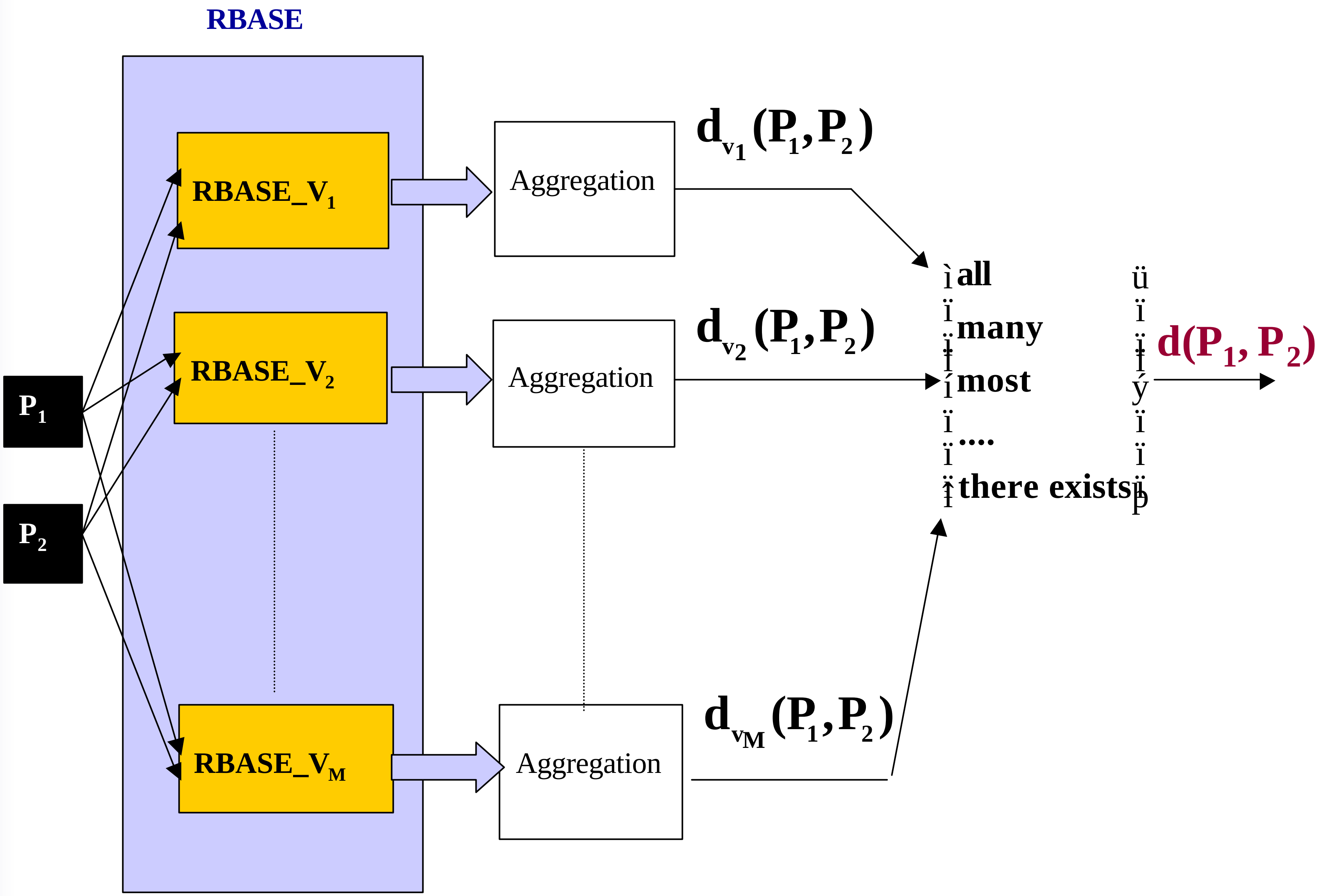
- **Categorical data are represented by fuzzy sets rather than classical set**
  - **Example**: The factor **DATA** of the COCOMO model

Low	Nominal	High	Very high
D/P<10	10<=D/P<100	100<=D/P<1000	D/P>=1000



- **Each selected attribute has a weight expressing its importance, U_k**

Evaluation of software projects similarity



Individual similarities

$$
d_{v_j}(P_1,P_2) = \begin{cases} \max\limits_k \min(\mu_{A_k}^{v_j}(P_1), \mu_{A_k}^{v_j}(P_2)) \\ \text{max - min aggregation} \\ \text{ou} \\ \sum\limits_k \mu_{A_k}^{v_j}(P_1) \times \mu_{A_k}^{v_j}(P_2) \\ \text{sum - product aggregation} \end{cases}
$$

Overall similarity

$$
d(P_1,P_2) = \begin{cases} \text{all of } d_{v_j}(P_1,P_2) \\ \text{most of } d_{v_j}(P_1,P_2) \\ \text{many of } d_{v_j}(P_1,P_2) \\ \text{at least four of } d_{v_j}(P_1,P_2) \\ \ldots \\ \text{there exists of } d_{v_j}(P_1,P_2) \end{cases}
$$

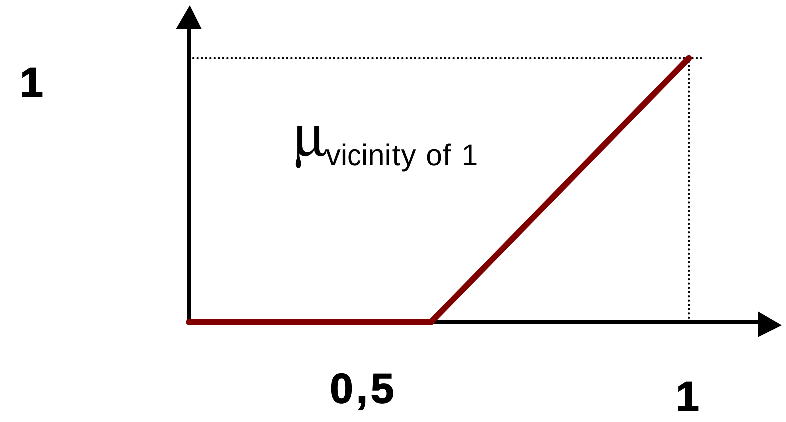
Company

$$
d(P_1,P_2) = \sum_{j=1}^{M} w_j d_{v_j}(P_1,P_2)
$$

$$
w_j(P_1,P_2) = Q\left(\frac{\sum_{k=1}^{j} u_k}{T}\right) - Q\left(\frac{\sum_{k=1}^{j-1} u_k}{T}\right)
$$

- **Adaptation**
  - **Two questions**
    - **1- How many similar projects will be used in the adaptation?**
    - **2- How to adapt the chosen analogies in order to generate an estimate for the new project?**
  - **In the literature, there is no clear rule to guide the choice of the number of similar projects, K**
    - **In general K=2**
    - **Suppose that the first three similar projects to the new project P have the following distances: 3.00, 4.00 and 4.01**
    - **When K=2, we consider only the two first projects**
    - **Why we have not take into account the third projects?**

- **Solution**
  - **What is 'P_i is closely similar to P'?**
  - **The $d(P_i, P)$ is in the vicinity of 1**



- **Adaptation formula:**

$$\mathrm{Effort}(P) = \frac{\sum_{i=1}^{N} \mu_{\text{vicinity of 1}}(d(P, P_i)) \times \mathrm{Effort}(P_i)}{\sum_{i=1}^{N} \mu_{\text{vicinity of 1}}(d(P, P_i))} \qquad (3)$$

If $\mu_{\text{vicinity of 1}}(x) = x$ then (3) is exactly the ordinary weighted average

Conclusions and Future work

- **We have propose a new approach for software cost estimation: Fuzzy Analogy when software projects are described by categorical data**
- **Fuzzy Analogy is also applicable when the variables are numeric (no uncertainty)**
- **Advantages of Fuzzy Analogy**
  - It can handle correctly the imprecision and the uncertainty when describing software project
  - It can be easily adapted to the needs of each organization (RIM linguistic quantifiers, Vicinity of 1,...)

- **Empirical validation of Fuzzy Analogy is based on**
  - COCOMO'81 dataset
  - **F_ANGEL**: A Software prototype based on Fuzzy Analogy

    (**To be submitted at 8th IEEE Metrics, June, Ottawa, Canada)**

- **Building prediction systems by analogy that satisfy <u>Soft Computing</u>:**
  - Tolerance of imprecision (Fuzzy Logic)
  - Learning (Neural Networks)
  - Uncertainty (Belief networks, genetic algorithms,...)

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