Enhancing the System Development Process Performance: A Value-Based Approach

M. Mastrofini[ab], G. Cantone[a], F. Shull[b], M. Diep[b], C. Seaman[bc], **D. Falessi**[ad]

[a] University of Rome "Tor Vergata"

[b] Fraunhofer Center for Experimental Software Engineering

[c] University of Maryland, Baltimore County

[d] Simula Research Laboratory

Summary

- **Vision**
- **Problem context**
- **Research goal**
- **Our proposal**
  - Scope
  - Multi Criteria Decision Making
  - Problem Characterization
  - Formulating a Quantitative Model
  - Impact Vectors
- **Experimental Evaluation**
- **Conclusions**
- **Work in Progress**

Vision

- Planning and controlling the system development process is a hard task for a project leader.
  - Project leaders needs to make decisions which take into account a number of aspects, including:
    - Availability of assets and competences.
    - Previously enacted processes in the organization.
    - Certifications the system is required to obtain.
    - Standards to comply with
    - Interactions among process activities.
    - Contextual factors and constraints
    - Allocated budget and schedule.
    - …

The goal of this research is to provide supportive information for decisions related to the system development process.

Problem context

- A well-structured development process is compulsory for organizations striving to produce systems of **great complexity** and of **high quality**.

- When planning or controlling the development process of such systems, the project leader needs to consider their **practical advantage**.

Problem context

- There are **many choices** available for methods, processes, and tools that can facilitate important development process activities.
- The project leader should select those choices which both:
  1. **Meet** the given process constraints and goals (set by the organization context and practices).
  2. **Maximize** the value the project may get.

Understanding how to maximize the value derived from each choice requires a deep analysis.

Research Goal

- Our **research goal** is to provide a value-based approach for helping decision makers **to manage and control** a process model so to **enhance the performance of the process**, with respect to the actual state.

Research Goal

- The definition of the term “performance enhancement” is here deliberately left vague.
  – It refers to the existence of some organization level or project level performance goals (e.g. reduction of development time at unaltered quality or increment of verification efficiency in terms of detected defects per hour).

Multi-Criteria Decision Making

- A multi-criteria decision problem can be characterized as:
  1. A set of decision alternatives.
  2. A set of attributes for evaluating the alternatives, i.e. the criteria on which a decision should be based.
  3. The performance of each alternative in those attributes.

- Such problems are often associated to **conflicts among the attributes**, and hence their tradeoffs need to be analyzed and understood.

Multi-Criteria Decision Making

- In the context of Systems Engineering, "value" includes aspects other than just cost, e.g. project quality, process constraints, and risks.

- Therefore, **multi-criteria decision making** must be used for system-level choices.

Problem Characterization

- The first question we want to answer is:

What are the ***decision alternatives*** *and what are the* ***attributes relevant*** *for enhancing the* ***verification process****?*

Problem Characterization

- In general, every organization, and possibly every department or center of a company, has its own set attributes.
  - However, there will be commonalities to these attributes that can serve as a baseline.

- To obtain such a baseline, we performed an abstraction step in identifying candidate attributes from **several international standards, company guidelines, and both system and software literatures**.

Problem Characterization

- Currently, we have identified **fifty attributes** that can be associated to a verification task, including:
  - ***cost*** (e.g. "acquisition" or "operation"),
  - ***required training*** (e.g. specific certification required or self-training),
  - ***expected performance*** (e.g. effectiveness or efficiency increase),
  - ***confidence in the estimated results*** of applying a given technique.

Formulating a Quantitative Model

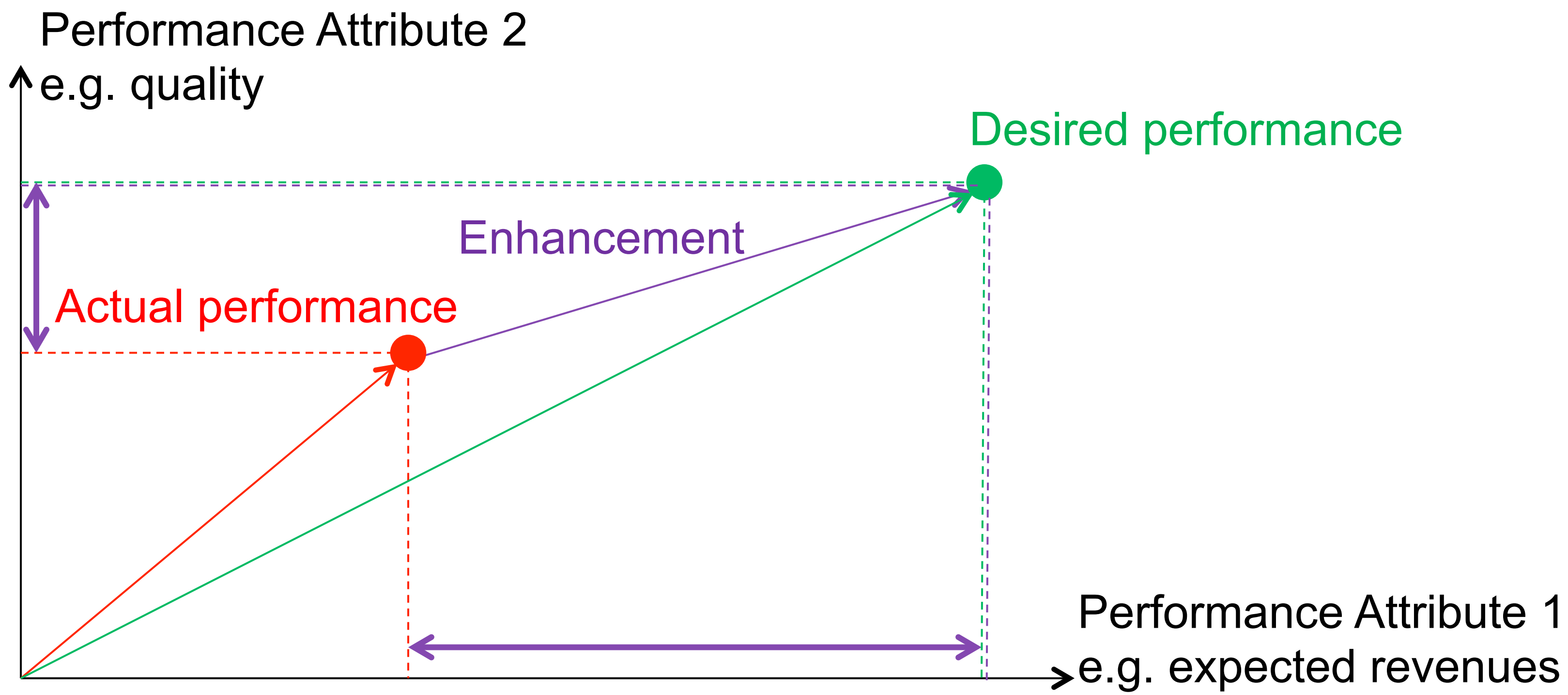
- Next step is to start building up a quantitative model to support our approach.
- So, we defined the **possible values that each attribute is allowed to assume**:
  - Some effectiveness-related attributes (e.g. percentage of detected defects with respect to the expected number of existing defects), a real number in the range [0 , ∞]
  - For the attribute qualifying the confidence in the estimated results of applying a given technique, a ordinal scale such as: {“very high”, “high”, “medium”, “low”, “very low”} could be employed, where each category is informally, but as unambiguously as possible, described.

Our Proposal: Impact Vectors

- We have defined:
  - Relevant attributes for a verification technique.
  - Accepted values for each attribute
- So, we can now represent a **verification technique as a point in a multidimensional space**.
  - Dimensions of the space are the attributes of interest.
  - Each coordinate’s value belongs to the accepted values for that attribute.
- **We name such a point “impact vector”.**
  - Example: impact vector for a technique T composed of three dimensions (instead of the fifty we identified), i.e. cost ($), effectiveness (real value in [0,∞]) and time (hours), could be: IV_T=<1000, 0.7, 3>.

Our Proposal: Impact Vectors

- Why to introduce Impact Vectors?
- To support process performance enhancement.



Our Proposal: Impact Vectors

- An impact vector can be associated to **a strategy**., i.e. a **set** of verification techniques that are applied in a given **order**.

- The impact vector of **a strategy** is a ***composition*** of the techniques' impact vectors.

Our Proposal: Impact Vectors

- For some **coordinates**' values of the strategy impact vector, "composition" means to **sum** the coordinates' values of the techniques' impact vectors (e.g. cost of the strategy).

- For other coordinates, the definition of composition is much more complicated.
  - E.g. the effectiveness of a strategy composed of two different techniques is not the sum of the effectiveness of the two technique considered independently. (we'll come back on this point)

Our Proposal: Impact Vectors

- **Base Performance Vector** (BPV): it is a vector which coordinates' values are the **current values for the actual status**.
  - E.g. current cost and effectiveness of the verification process being applied.

Our Proposal: Impact Vectors

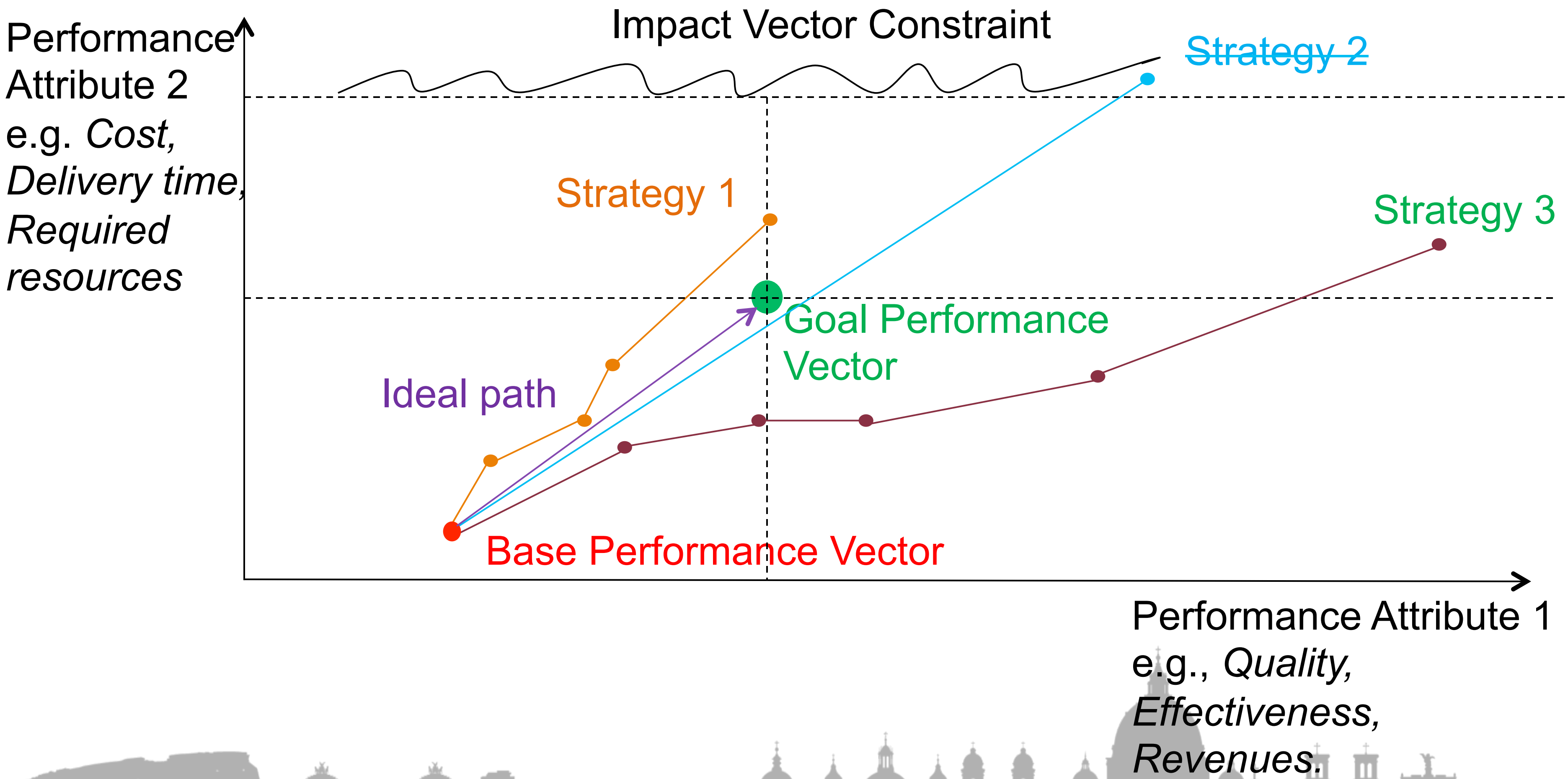
- **Goal Vector**: it is a vector that expresses the desired performance.
  - The goal vector represents a project's or company's **performance goal**, after formalizing it in quantitative terms.
  - The definition of a goal vector consists in formalizing the term "**performance enhancement**" for the specific context.

Our Proposal: Impact Vectors

– **Impact Vector constraint**: it is a **rule** which limits the set of admitted values for a feasible vector.
  - E.g. “project development is requested not to take more than **5 years**”.

Our Proposal: Impact Vectors (5/5)

- Example.



Experimental Evaluation - Rationale

- In order to make decisions for choosing the right strategy, the impact vector approach needs a solid **knowledge base**.

- This, in the form of a database, should support the estimation of the impact of a technique and of a set of techniques.

- Thus, it should contain:
  – historical data on techniques' **performances**
  – the **compositional model** (to estimate the impact of a set of techniques)

Experimental Evaluation - Rationale

- We have started experimenting **with two verification techniques**: Functional Testing (**FT**) and Perspective-Based Code Inspection (**PBCI**)

- The aim is to understand their **performances** and a model for their **composition**.

Experimental Evaluation – Research question

- Two available verification techniques: FT and PBCI
- Each verification technique can last 0,1 or 2 hours.
- Available time: 2 hours

- Which verification strategy (i.e. set of techniques) to adopt in 2 hours?
  - FT, FT
  - FT, PBCI
  - PBCI, FT
  - PBCI, PBCI

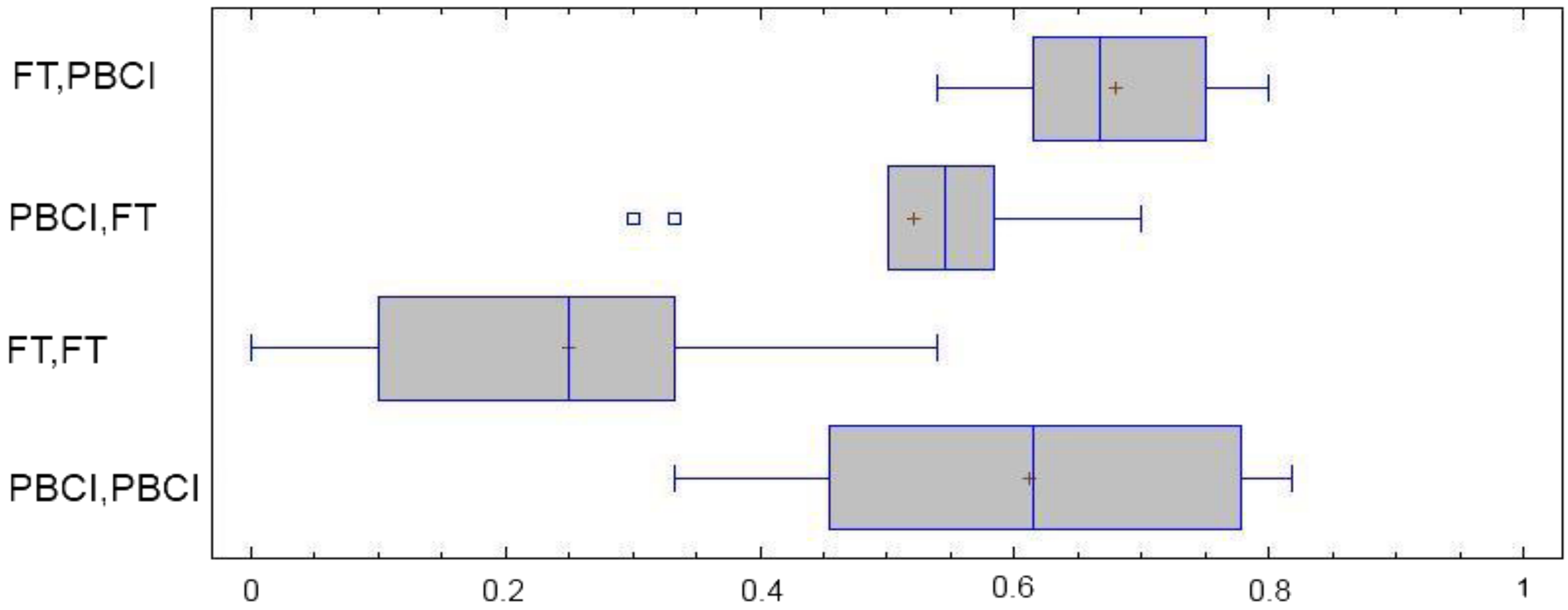
Experimental Evaluation – Dependent Variables / Coordinates

- **Recall** :: (True Positive) /(True Positive + False Negative) = proportion of actual identified defects over the number of existing defects

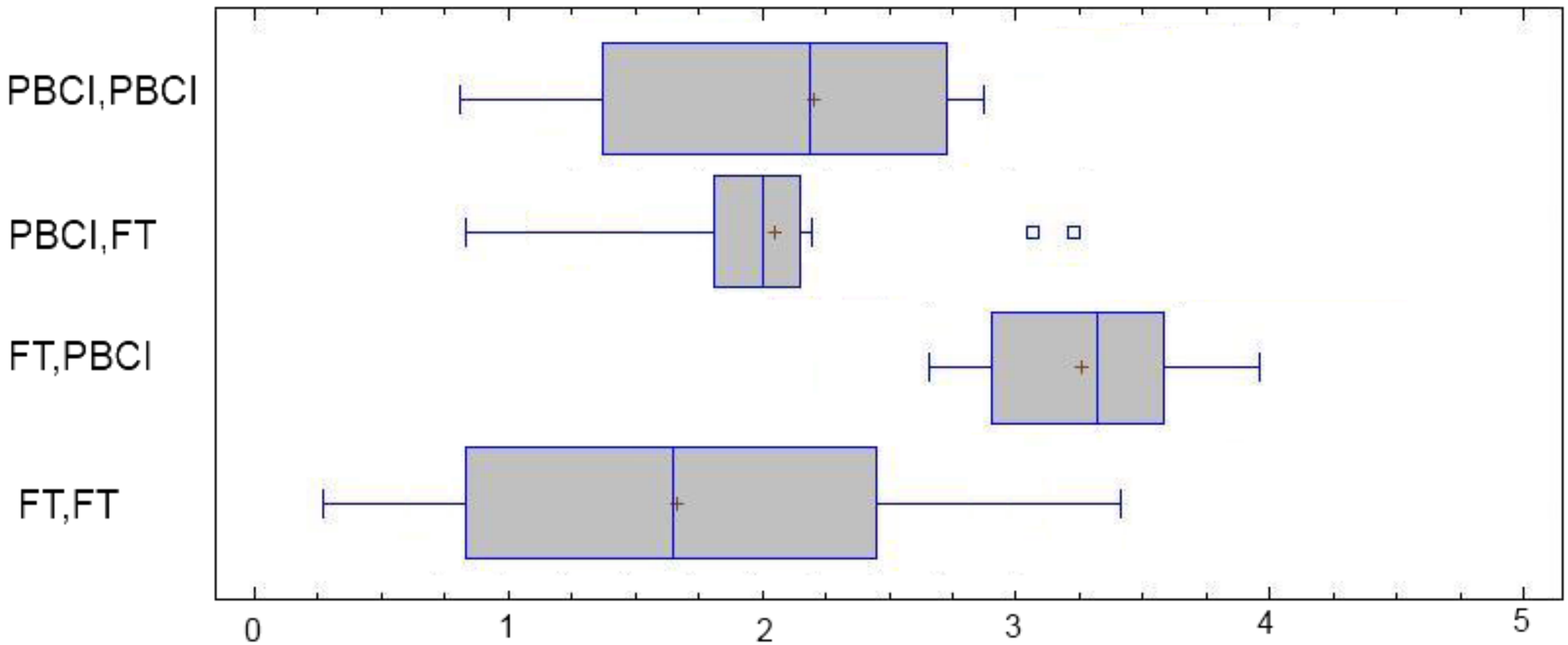
- **Defect detection rate** :: True Positive / Time = number of actual identified defects per hour.

- **False positive rate** :: (False Positive) / (False Positive + True Positive) = proportion of false identified defects over the total number of identified defects

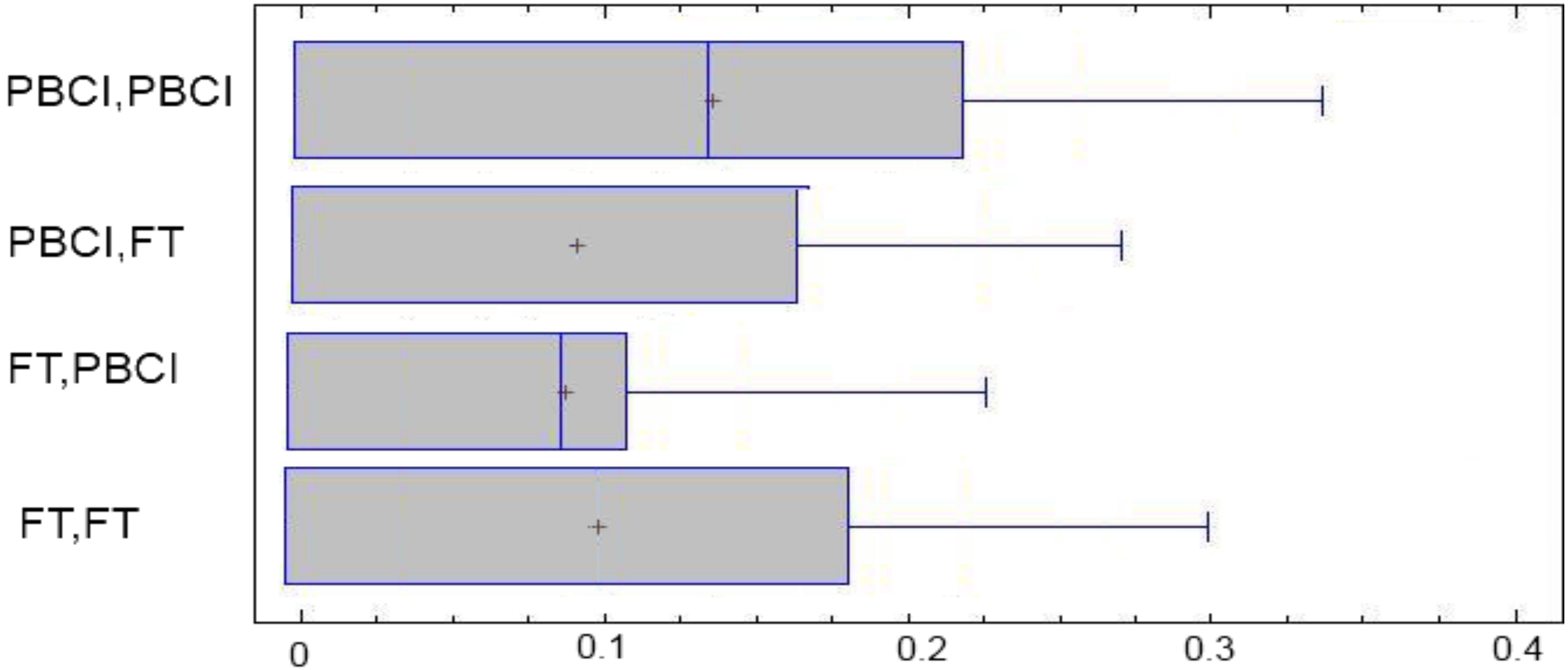
Experimental Evaluation – Results - Recall



Experimental Evaluation – Results – Defect Detection Rate



Experimental Evaluation – Results – False Positive Rate



Experimental Evaluation – Results

Treatment	Metric	End of the 1st stage	End of the 2nd stage
FT, PBCI	Recall	18.63	67.91
	Defect detection rate	2.31	3.22
	% of false positives	19.44	9.13
FT, FT	Recall	18.93	24.98
	Defect detection rate	2.31	1.67
	% of false positives	19.44	9.72
PBCI, PBCI	Recall	54.13	61.23
	Defect detection rate	3.36	2.15
	% of false positives	20.06	12.44
PBCI, FT	Recall	50.13	52.05
	Defect detection rate	3.36	2,00
	% of false positives	20.06	9.54

1) The Saturation effect

2) The order effect

3) The importance of the final goal

Work in Progress

- Currently working on the **elicitation of Impact Vectors** for:
  1. Inspections on:
     I. system artifacts
     II. software artifacts
     III. FPGA artifacts.

- Implementation of a **software tool** to support the practical use of impact vectors.

- Definition of a **methodology to integrate Impact Vectors** into an already existing measurement strategy.

- Extension of the Impact Vector Model to including, managing and leveraging **qualitative and incomplete data**.

- Further **experimentation**.

Enhancing the System Development Process Performance: ... ue-Based Ap...

Thank you!

M. Mastrofini[ab], G. Cantone[a], ..., C. Seaman[bc], **D. Falessi**[ad]

[a] University of ... "Tor Vergata"

... Center for ...mental Software ...gineering

[c] University of Maryland, Baltimore County

[d] Simula Research Laboratory