Course "Spezielle Themen der Softwaretechnik"

Agile Methods: Pair Programming (PP)

Lutz Prechelt
Freie Universität Berlin, Institut für Informatik
http://www.inf.fu-berlin.de/inst/ag-se/

- Definition
  - Related methods
- An example study of PP
- Questions and empirical results:
  - Relative raw productivity?
  - Quality of resulting design and code?
  - Benefits from more people being familiar with code?
  - ... from interruptability?
  - Influence on motivation?
  - Recommendations for learning pairing, changing?
- Our PP research approach
  - data gathering, evaluation

Learning objectives

- Understand which factors influence PP
- Understand the potential benefits from PP
- Get an overview of the current state of knowledge about these benefits
  - and some deficiencies of the studies so far
- Understand why they are difficult to measure
- Understand the research approach of AG Software Engineering with respect to understanding PP

Definition: Pair Programming

Freie Universität Berlin

From [WilKesCun00]

"In pair-programming,

- two programmers jointly produce one artifact (design, algorithm, code, etc.).
- The two programmers are like a coherent, intelligent organism working with one mind, responsible for every aspect of this artifact.
- One partner is the 'driver' and has control of the pencil/mouse/keyboard and is writing the design or code.
- The other person continuously and actively observes the work of the driver -- watching for defects, thinking of alternatives, looking up resources, and considering strategic implications of the work at hand.
- The roles of driver and observer are deliberately switched between the pair periodically.
- Both are equal, active participants in the process at all times and wholly share the ownership of the work products whether they be a morning's effort or an entire project."

Related methods

Distributed Pair Programming (DPP):

- The partners are not physically in the same room and use a separate computer each
- Their interaction is supported by a collaborative editor and chat, audio conferencing, perhaps video.

Side-by-side Programming (SbS [Cockburn05]):

- A task is assigned to a pair of programmers
- Each programmer has his/her own computer
- Allows them to split the task into subtasks and work on each subtask individually, but in close coordination
- The partners are sitting close to each other in one room and interact directly

Related methods (2)

Ping-Pong Pair Programming (PPPP):

- PP with frequent role change, driven by Test-Driven Design
- Driver/observer role switching follows a fixed rule:
  - one partner writes a test,
  - the other the implementation,
  - then vice versa (in rather tiny increments)

Ways towards understanding PP: Blackbox perspectives

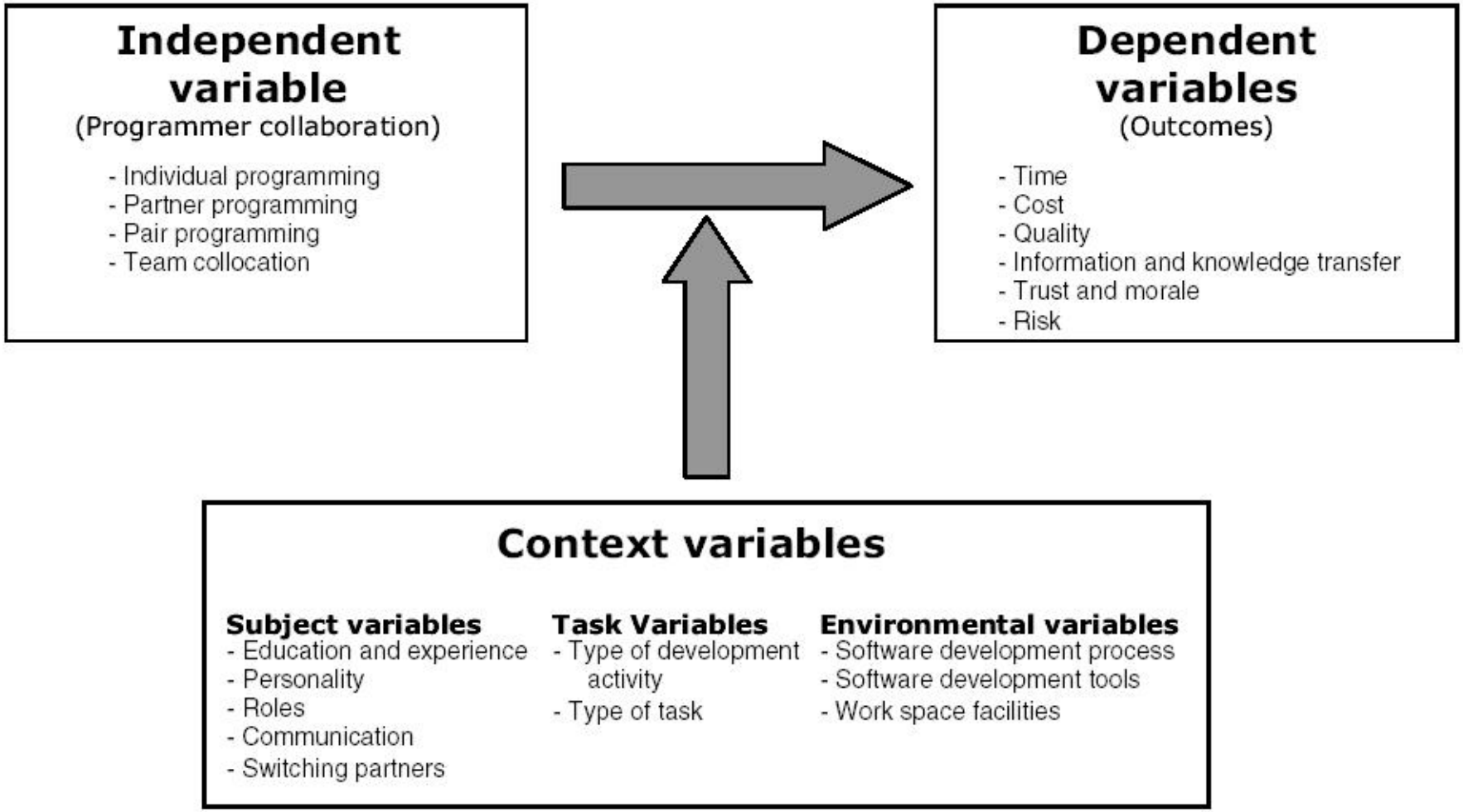


Figure 1: An initial framework for research on pair programming.

source: [GalAriDyb03]

Studies on PP

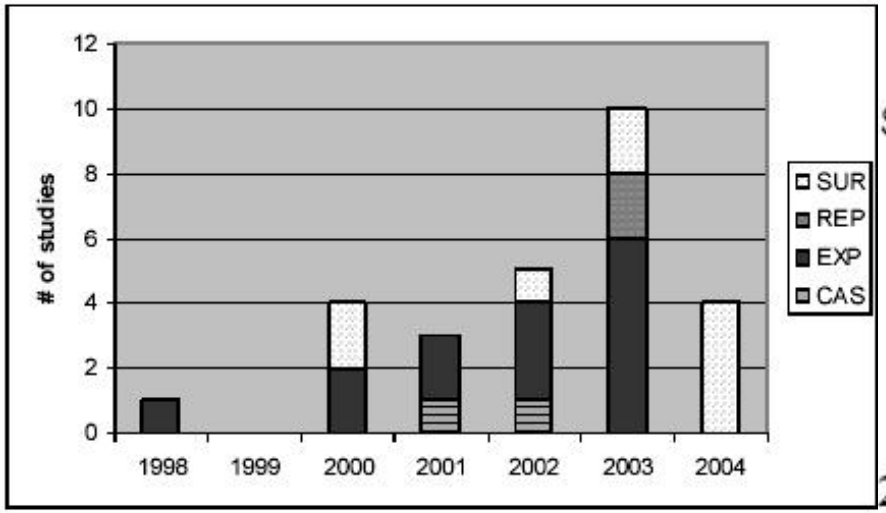
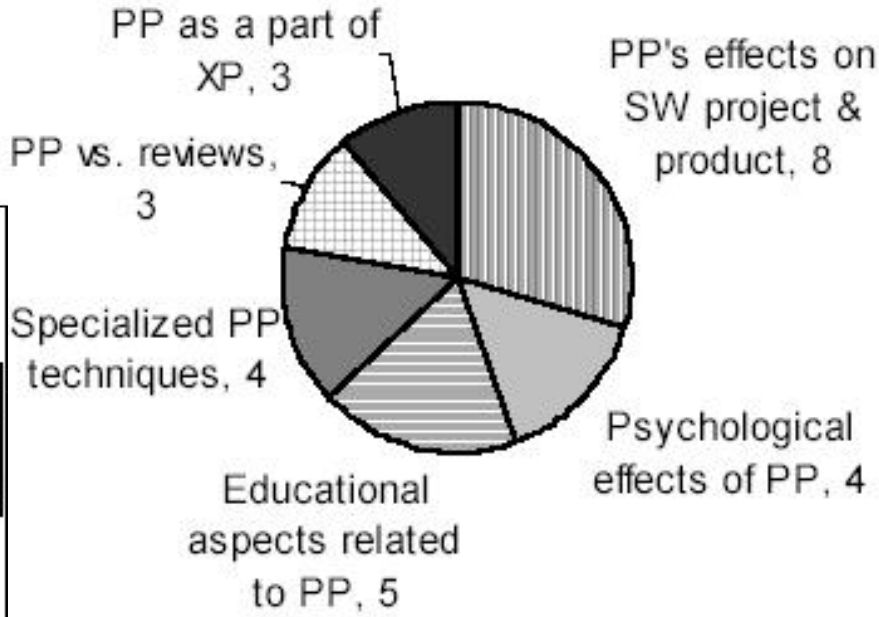


Figure 1. Studies on pair programming.



2. Distribution of empirical studies based on their research focuses.

- source: [HulAbr05]: "A Multiple Case Study on the Impact of Pair Programming on Product Quality"

[Nosek98] "The case of collaborative programming" (1)

Freie Universität Berlin

Survey+experiment, compared pairs to individual programmers:

- "A ... field experiment ... using experienced programmers who worked on a challenging problem important to their organization, in their own environments, and with their own equipment."
  - 15 full-time system programmers from a program trading firm, developing a consistency checking program for a Sybase DB; Unix, X-Windows, C
- Hypotheses:
  - "Programmers working in pairs will produce more readable and functional solutions"
    - READABILITY variable: 0 unreadable, 2 fully readable, 1 in between
    - FUNCTIONALITY variable: degree 0...6 of achievement of objectives
  - "Groups will take less time on average to solve the problem"
  - "Programmers working in pairs will express higher levels of confidence about their work (CONFID) and enjoyment of the process (ENJOY)"

[Nosek98] "The case of collaborative programming" (2)

Freie Universität Berlin

- 15 programmers randomly assigned into
  - 5 pairs
  - 5 individual programmers
- All solve the same task: DBCC (database consistency check)
- Worktime limited to 45 minutes

- Afterwards, each person answered several questions regarding CONFID and ENJOY
  - The exact questions used are not indicated in the article
  - The scale used for the results is also not explained

- READABILITY and FUNCTIONALITY were each judged by two graders for each solution (and had over 90% agreement)

[Nosek98] Results

Freie Universität Berlin

Comparison of Individual and Team Measurements

Variable	Control Group (Individuals) mean (st. dev.)	Experimental Group (Teams) mean (st. dev.)
Performance Scores:	n = 5	n = 5
READABILITY	1.40 (0.894)	2.00 (0.000)
FUNCTIONALITY	4.20 (1.788)	5.60 (0.547)*
SCORE	5.60 (2.607)	7.60 (0.547)*
TIME (minutes)	42.60 (3.361)	30.20 (1.923)
Satisfaction Measures:	n = 5	n = 10
CONFID	3.80 (2.049)	6.50 (0.500)*
ENJOY	4.00 (1.870)	6.60 (0.418)*

indiv. are 41% slower, but difference is not significant

*less than 1 in 20 that results are due to chance

according to two-sided t-test

[Nosek98] Conclusions

- Hypothesis 1 (pairs' solutions are more readable and more functional, SCORE = READABILTY + FUNCTIONALITY):
  - Is confirmed
- Hypothesis 2 (faster):
  - Is not confirmed, as the difference is not statistically significant
- Hypothesis 3 (CONFID, ENJOY):
  - Is considered confirmed

[Nosek98] Strengths & weaknesses

- Good:
  - "real" programmers
  - "real" task

- Bad: A lot of interesting information is missing in the short 4-page article:
  - Did the participants have any experience in PP?
  - Were they prepared for PP in some way?
  - What attitude did they have towards PP before the experiment?
  - To what degree was design relevant for solving the task?
  - How did the pairs work together (communication, role switching, etc.)?
  - Did the partners learn from each other during the PP session?

- John T. Nosek: "The Case for Collaborative Programming", Communications of the ACM 41(3), March 1998, pp. 105-108

Questions about PP

- Raw productivity compared to two separate programmers?
  - Cost or time per functionality
- Quality of resulting design?
- Quality of resulting code?
- Benefits from more people being familiar with code?
- Benefits from interruptability?
- Influence on motivation?
- Calculation of the overall cost-benefit
- Learning process?
- Recommendations for pairing, changing, etc.?

Subsequent slides explain the questions and the respective state of knowledge

PP: Raw productivity?

Processing time:

- PP vs. solo
  - Completion was 41% longer for individuals than for pairs, but not statistically supported.
    J. T. Nosek [Nosek98]
  - Pairs complete their assignments 40-50% more quickly.
    Laurie Williams, Robert R. Kessler, Ward Cunningham, and Ron Jeffries [WilKesCun00]

- SbS vs. PP vs. solo
  - SbS 60% and PP 75% of the time of solo.
    Jerzy R. Nawrocki, Micha Jasiñski, Lukasz Olek, and Barbara Lange [NawJasOle05]

PP: Raw productivity?

Effort

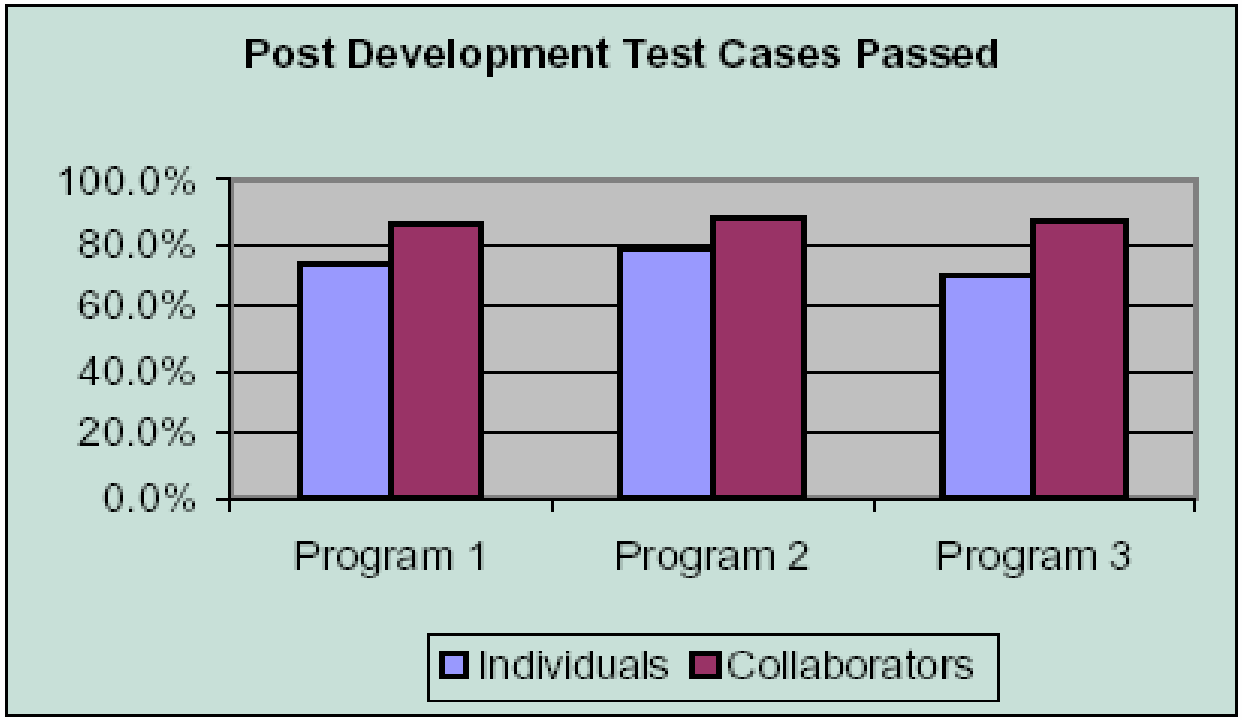
- PP vs. solo
  - Pairs spent approximately only 15% more effort on a task than solo developers (Williams [Williams02])
  - 10% increase (Ciolkowski and Schlemmer [CioSch02])
  - 21% increase (Lui and Chan [LuiCha03])
  - New team members who were added to a delayed project reduce the assimilation and mentoring times and thus improve the productivity of the whole team (survey + case study, Williams, Shukla, Antón [WilShuAnt04])
  - Pair programming is less productive than "XP done by solo developers" (Nawrocki and Wojciechowski [NawWoj01])

- SbS vs. PP vs. solo
  - Overhead for side-by-side programming was as small as 20%, while for PP it was about 50% (Nawrocki, Jasiñski, Olek, Lange [NawJasOle05])

PP: Quality of resulting design/code?

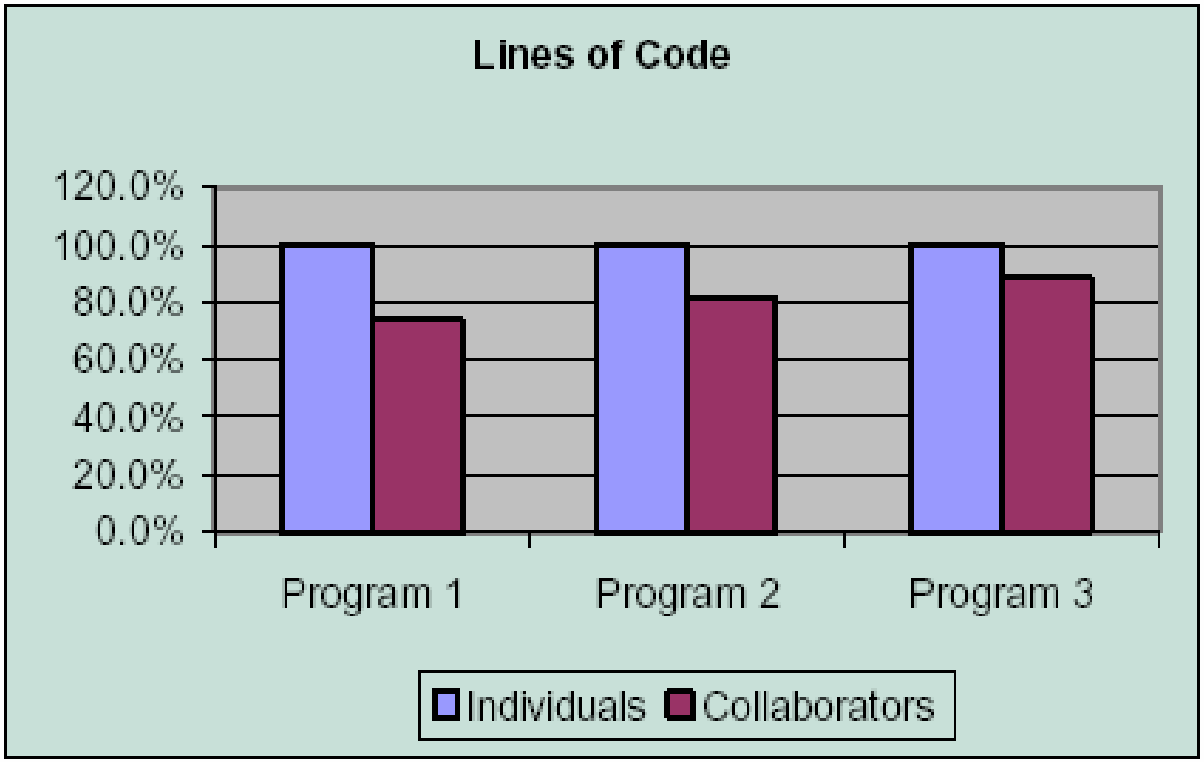
Defects

- Decreased defect rates [Williams01], [Jensen03], [Tomayko02]
- Fewer failures in automated test [WilKesCun00], [CocWil01]:
  - The programs produced by pairs had about 15% fewer failures according to the automated test cases run by the teaching staff



PP: Quality of resulting design/code?

- Functionality:
  - [Nosek98]: Higher degree to which pairs solved the problem
- Readability:
  - [Nosek98]: Improved readability from pairs
- Fewer lines of code:
  - [CocWil01]: "We believe this is an indication that the pairs had better designs."



PP: Quality of resulting design/code?

- Design
  - Pair programming improved productivity most in demanding design tasks (experiment, [LuiCha03])
    - design of study can hardly be taken serious as PP
  - Pairing was not found useful in simple, rote tasks (case study, Matthias M. Müller and Walter F. Tichy [MulTic01])

- Coding standards
  - Coding standards are followed more accurately with the peer pressure to do so (experiment + interviews, [CocWil01])

PP: Benefits from more people being familiar with code?

Freie Universität Berlin

- Many projects have strong individual code ownership:
  For each code module, only one programmer understands it well and only that person makes all modifications
  - and only this person will almost never misuse the module
- This often hampers project progress when corrections need to be made by someone who is already overworked
  - or hamper quality if a complex module is often misused
- PP will greatly reduce that problem

- How big is this benefit in terms of progress and quality?

- No quantitative results are known, as this is immensely difficult to measure
  - It requires project-level observations

PP: Benefits from interruptability?

- Frequent interruptions of programmers' work is known to be problematic for productivity and quality
  - Lost time to get back into the problem again afterwards
  - High probability of committing an error
- Potentially in PP, productivity hardly breaks down when an interruption occurs
  - one person handles the interrupt, the other continues
- In interruption-rich situations, this might be a big advantage
  - depending on phase/activity (most useful during pure coding)
  - depending on who is driver (most useful if the observer can handle the interruption)
- But the effect is very difficult to measure quantitatively

- No empirical results are known

PP: Benefits from learning from one another?

Freie Universität Berlin

- Only anecdotal evidence
  - [Belshee05]: New programmer without OOP knowledge came into a PP project heavily using C++ template metaprogramming.
  - After only four weeks he was fit enough to train another newcomer all alone, at the same time tackling even parts of the 600-class code base he had never seen.
  - [Belshee05]: Promiscuous PP (changing pairs every 90 minutes) lead to all 11 members of the team learning a neat IDE editing feature within just 1 day
    - the paste stack, which had been discovered only accidentally
- Again, the effect is very difficult to measure quantitatively
  - It requires project-level observations
- No empirical results are known

PP: Influence on motivation?

All studies agree that PP is generally rather motivating

- A survey [WilKesCun00] explains that with a positive form of "pair pressure":
  - Both partners want to show their talent and quality work
  - The participants are highly concentrated on their work and keep each other on on task
    - no reading emails or surfing the web etc.

Exceptions:

- Some programmers reject PP completely
  - usually without even trying it out
  - Programmers with longer experience tend to be more skeptical
- Pairing people with highly different skills is often problematic
  - The more capable partner is slowed down too much

PP: Calculation of the overall cost-benefit

Summarization of the effects of pair programming and calculation of the overall cost-benefit ratios for adopting PP

- Increase of 5% on the total project costs caused by PP
  - experiment, [Müller03]
- Pairs have a higher efficiency and overall productivity rate compared to individual developers, and pair programming increases the business value of a project
  - experiment, [WilKes03]

- The results lack ecological credibility and are highly preliminary

PP: Learning process?

What happens when trying to start with PP?

How best to start with PP?

- Some authors claim that PP beginners quickly find their way into the process [WilKes00]
  - At the university, the students were generally adjusted to PP after the first assignment
  - In industry, this adjustment period has historically taken hours or days, depending upon the individuals

- Details of the learning process are hardly known and little constructive advice is available so far
- We may need a description of steady-state PP first

PP: Recommendations for pairing?

- [KatWil04, KatWil05] claims that personality type (MBTI) and self-esteem are not critical for their compatibility
  - but members prefer to pair with someone who have similar technical skills
- [Domino03] suggests that the members may need some level of specific interpersonal skills, in particular conflict resolution skills
  - quasi-experiment found some correlation of performance to results of Rahim Organizational Conflict Inventory (ROCI-II)
- [MuelPad04] suggests that subjectively feeling comfortable with each other correlates with shorter development times
  - but causality is unknown (experiment postmortem interview)

PP: Recommendations for pairing?

- [CaoXu05] suggests
  - pairing members of high and low competent levels is less enjoyable for the more competent participant
    - while the less competent participant took benefit
  - high competence level leads to deep-level thinking
    - and both participants enjoy the experience

- [Belshee05] claims that switching the pairs very frequently is highly beneficial in a low-skill situation
  - "Promiscuous Pair Programming":
    Almost continually one partner is new to the task
  - Leads to continuous "beginner's mind" and fast learning

PP: Recommendations for changing roles?

- There are some informal recommendations to keep the frequency of changes sufficiently high
  - But based on mostly subjective evidence

- Hardly any specific recommendations are known

PP: How does it work?

- No studies answer this question
  - Neither how nor why nor when PP works well or not-so-well
  - Today PP is a Black Box

- We need decision criteria for when to use PP.
- We need guidance for PP process improvements:

- Description of driver and observer role behavior
  - and advice for when to switch roles
- Catalog of best practices
- How to optimize PP towards the various goals:
  - Knowledge transfer,
  - integrating newcomers,
  - optimizing design,
  - optimizing correctness,
  - etc.

PP: How it works?
Our research approach

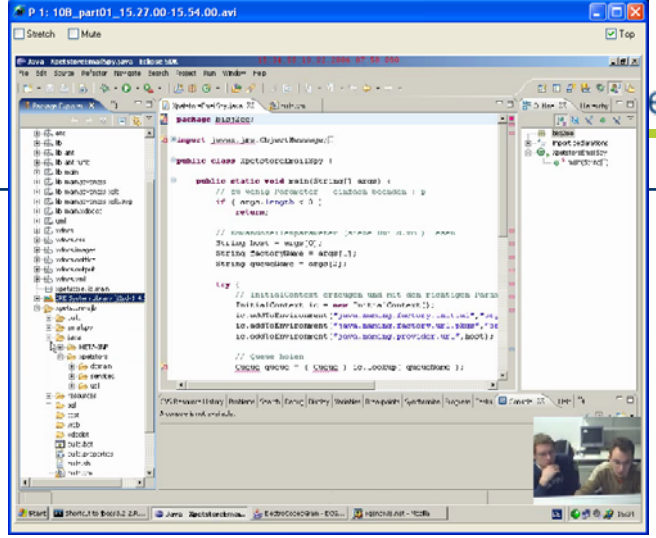
Freie Universität Berlin

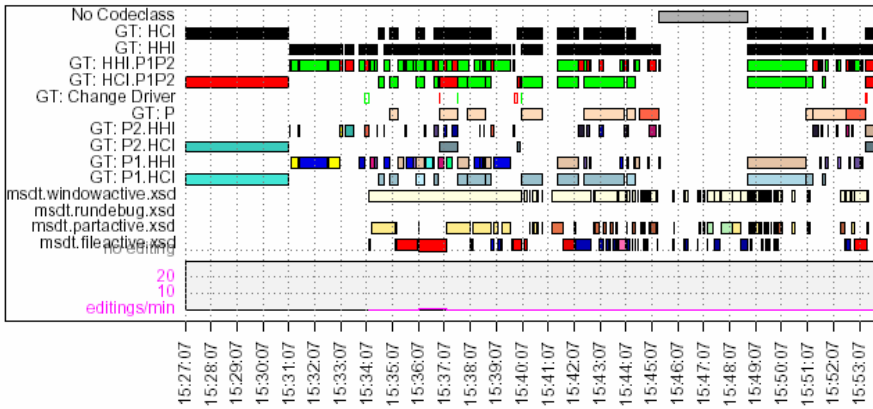
- Basic idea: Look <u>into</u> the process
  - Not just at its outcomes: Investigate the PP microprocess
- First obtain a detailed description of a typical PP microprocess
  - Perhaps concentrating on only a few aspects at first (e.g. knowledge transfer, strategy, role behavior, work modes)
- To do this, we need detailed data about PP sessions
  - Audio, Video (people and screen activity)
  - ElectroCodeoGram (ECG)
- We need a mix of data sources to satisfy all our requirements:
  - Observations of students allow to see multiple instances of equivalent problem-solving sessions for comparison.
  - Field observations of professional programmers allow to improve and validate the ecological validity of resulting models.

PP: How it works?
Our research approach (2)

Data evaluation approach:

- Conceptualize a few videos
  - Thus form a description vocabulary
  - Research method: Grounded Theory
- Use visualization to obtain an overview of the flow of events
- Form models and hypotheses
- Validate and refine them with further sessions
  - Use visualization of ECG data to find the relevant episodes quickly
- Identify helpful and damaging behaviors
- Describe them as patterns





Insights, models

Summary

- Pair Programming (PP) is the joint production of an artifact by two equal, active programmers with fully shared ownership
  - using only one keyboard and switching the driver role repeatedly
- PP has a substantial number of potential benefits
  - supported by anecdotal evidence
- Empirical results regarding productivity are somewhat mixed
- Empirical evidence regarding the other benefits is scarce, because measuring them is very difficult
  - because of their nature (deeply weaved into the project context)
- More research is needed
  - Talk to AG SE if you consider participating in such research

Thank you!