Course "Spezielle Themen der Softwaretechnik"

Agile Methods: Pair Programming (PP)

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- 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

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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
  - http://www.c2.com/cgi/wiki?VirtualPairProgramming
  - http://www.saros-project.org (Saros, see last few slides)
- 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
  - http://c2.com/cgi/wiki?PairProgrammingPingPongPattern
- Driver/observer role switching follows a fixed rule:
  - one partner writes a test,
  - the other the implementation,
  - then vice versa (in rather tiny increments)

Distributed Party Programming (DPP):

- work style like Side-by-Side programming
- but with more than 2 participants (say, 5)
- only possible with distribution and appropriate tool support

Ways towards understanding PP: Blackbox perspectives (quantitative)

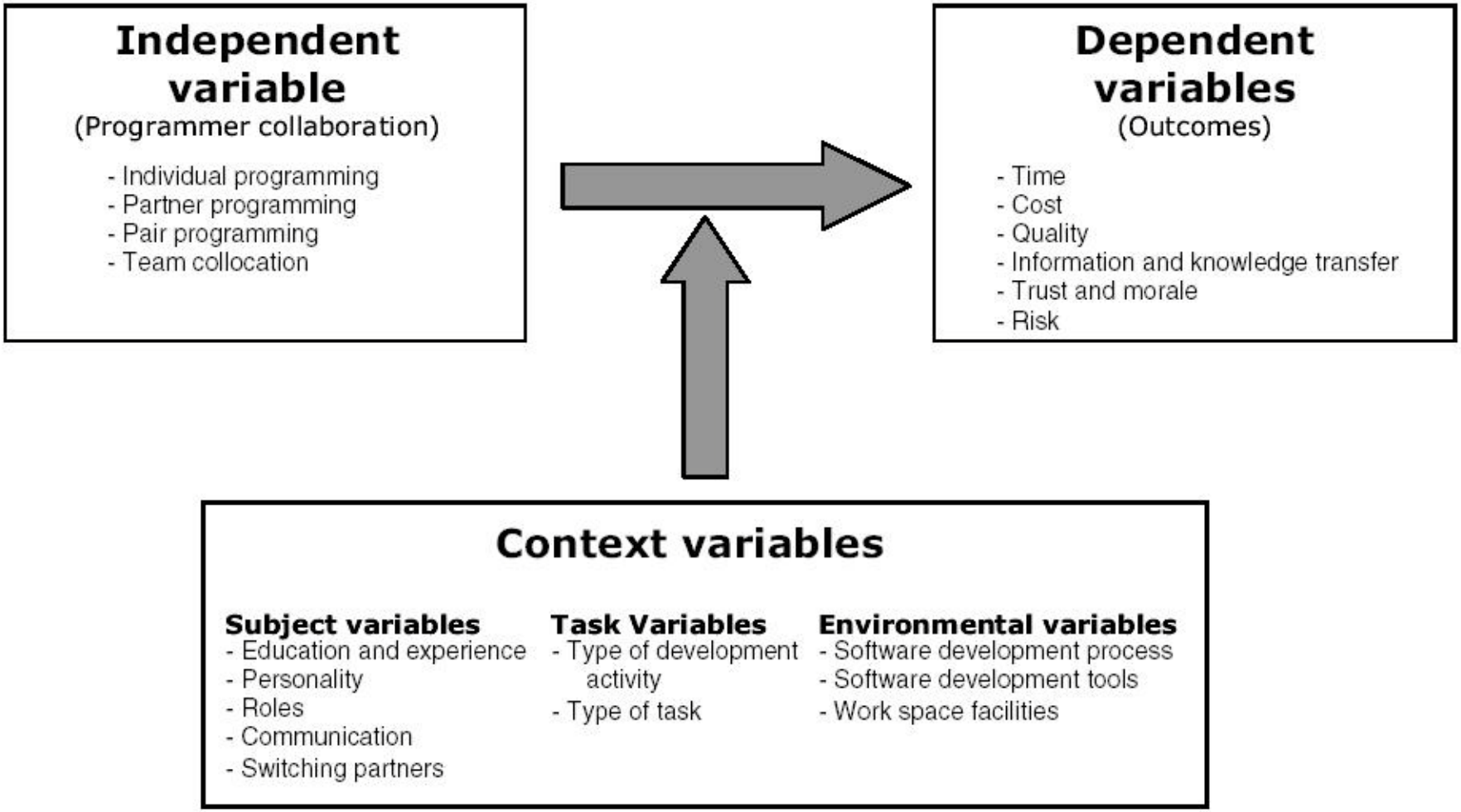


Figure 1: An initial framework for research on pair programming.

source: [GalAriDyb03]

Studies on PP

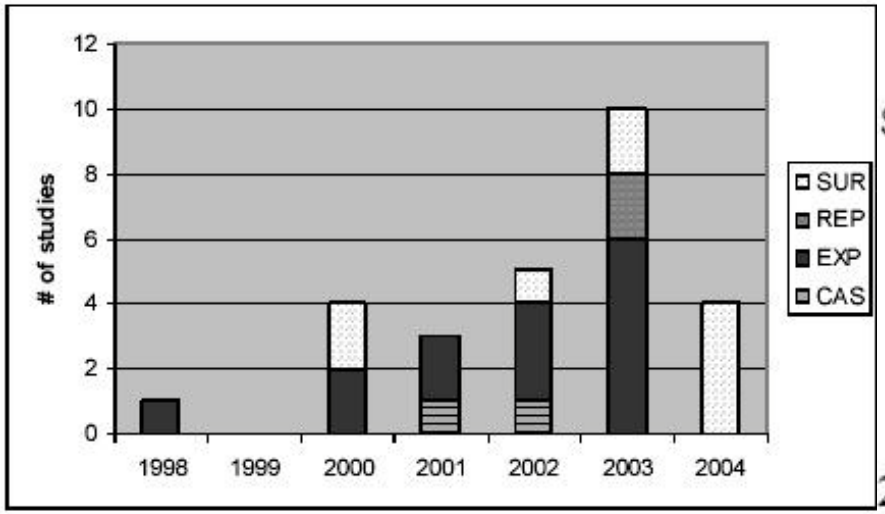
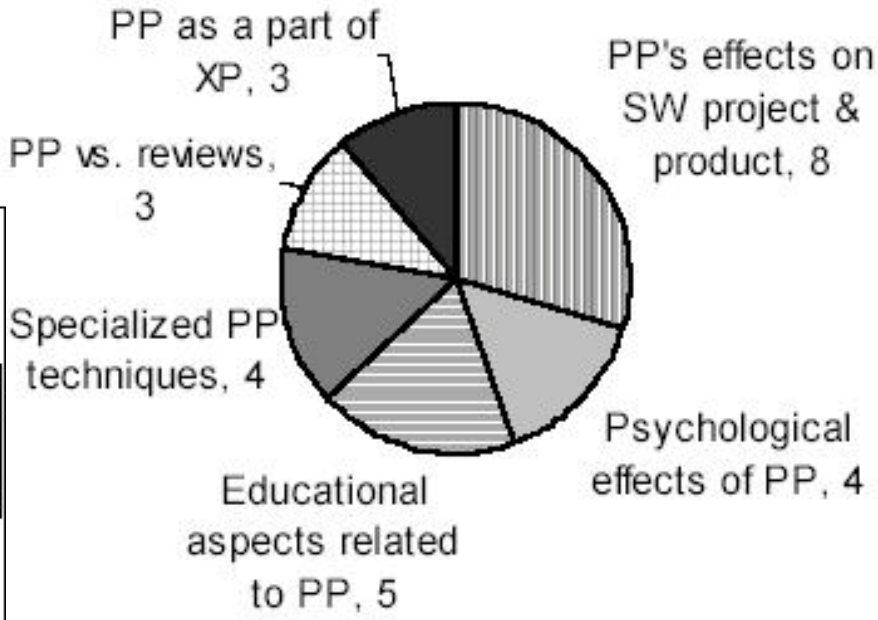


Figure 1. Studies on pair programming.



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)

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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)

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- 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

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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. take 41% longer, 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 = READABILITY + 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

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- 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

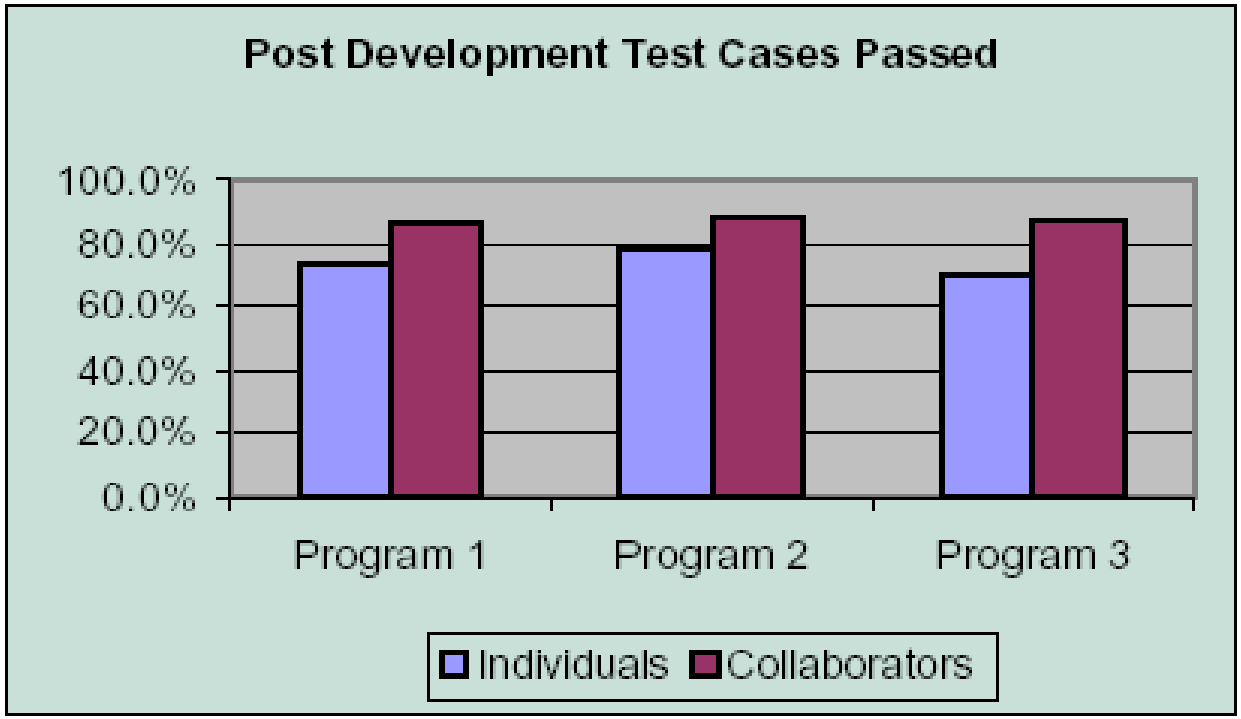
- PP vs. solo
  - Pairs spent approximately only 15% more effort on a task than solo developers (Williams [Williams02])
  - 10% increase (Ciolkowski and Schlemmer [CioSch02])
  - 21% increase (Lui and Chan [LuiCha03])
  - New team members who were added to a delayed project require less assimilation and mentoring time 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, Jasinski, Olek, Lange [NawJasOle05])

PP: Quality of resulting design/code?

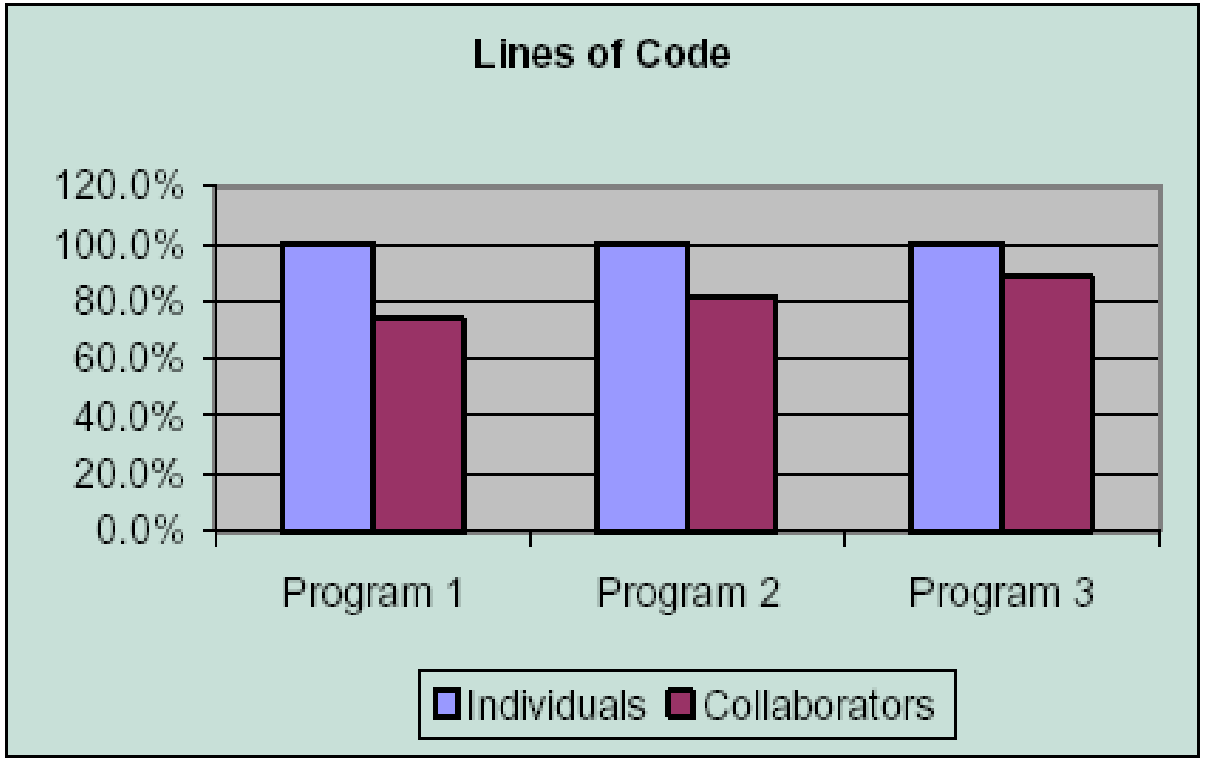
Defects

- 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
      - participants performed intelligence tests
  - 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?

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- 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 can do so with usually no errors.
  - 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 quantiative empirical results are known

PP: Benefits from learning from one another?

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- Only anecdotal evidence is available:
  - [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 quantitative 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 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 <u>extremely</u> different skills is problematic
  - The more capable partner may be 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]

- Both 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 <u>not</u> critical for pair compatibility
  - but members prefer to pair with someone who has 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 with 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 competence levels was 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
  - Claimed to lead 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:

- Catalog of best practices, regarding
  - communication and knowledge exchange
  - decision making
  - role switching
- How to optimize PP towards the various goals:
  - Knowledge transfer,
  - integrating newcomers,
  - optimizing design,
  - optimizing correctness,
  - etc.

PP: How does it work? Our research approach

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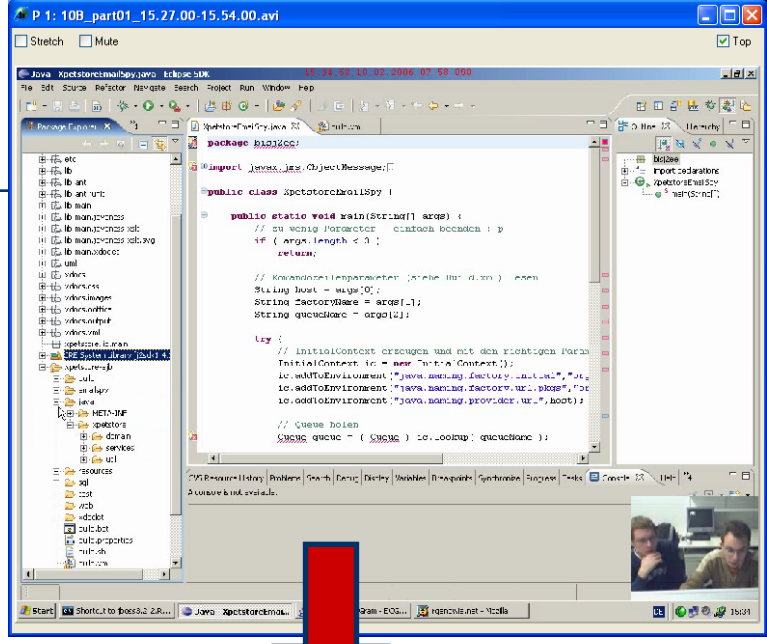
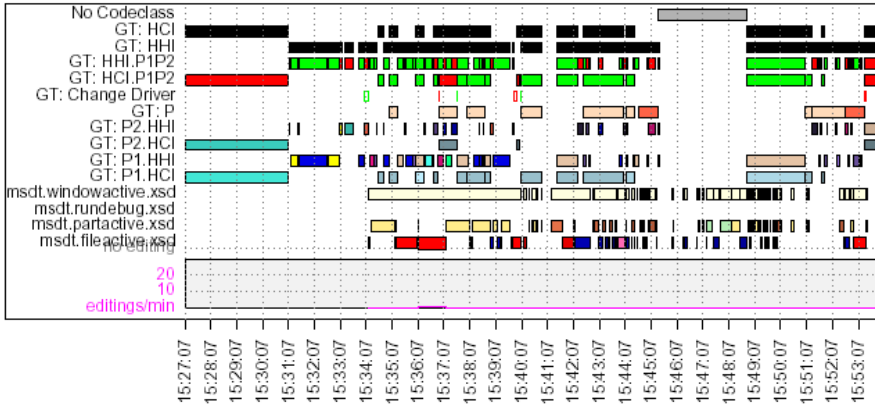
- Basic idea: Look <u>into</u> the process
  - Not just at its outcomes: Investigate the PP microprocess
- First obtain a detailed description of a typical PP microprocess
  - Perhaps concentrating on only a few aspects at first (e.g. knowledge transfer, strategy, role behavior, work modes)
- To do this, 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:
  - Laboratory observations (e.g. 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 does it work? Our research approach (2)

Data evaluation approach:

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





Insights, models

PP: How does it work? Methodological insights

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Defining consistent concepts ("codes") is very difficult

1. A perspective on the data is needed
   - to avoid drowning in detail.
   - Acts as a filter: what to encode, what to ignore
2. It is helpful to perform coding in pairs
   - For challenging vagueness and enforcing consistency
3. It is helpful to use structured code names
   - person.verb_object: "P1.propose_step", "P2.explain_state"

- We use the following perspective:
  - directly observable actions only, in particular communication
- We ignore anything requiring subjective judgement, such as
  - attribution of "helpful"/"unhelpful" to actions
  - attribution of emotions (happy, annoyed, surprised, focused, ...)

PP: How does it work?
Basic process concepts found

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product-oriented concepts

- ask_design
- challenge_design
- agree_design
- decide_design
- propose_design
- disagree_design
- amend_design
- remember_requirement
- challenge_requirement
- agree_requirement
- propose_requirement

other concepts

- mumble_sth
- say_off topic

process-oriented concepts

- ask_step
- explain_completion
- challenge_step
- agree_step
- agree_completion
- decide_step
- propose_step
- challenge_completion
- disagree_step
- amend_step
- explain_state
- ask_strategy
- agree_state
- challenge_strategy
- agree_strategy
- challenge_state
- decide_strategy
- propose_strategy
- propose_todo
- amend_strategy
- agree_todo

universal concepts

- explain_gap in knowledge
- ask_standard of knowledge
- explain_standard of knowledge
- think aloud_activity
- agree_hypothesis
- ask_knowledge
- challenge_activity
- explain_hypothesis
- agree_knowledge
- disagree_activity
- challenge_hypothesis
- explain_knowledge
- amend_activity
- disagree_hypothesis
- challenge_knowledge
- stop_activity
- amend_hypothesis
- disagree_knowledge
- agree_activity
- remember_source of information
- amend_finding
- explain_finding
- challenge_finding
- agree_finding

facade concepts

PP: How does it work? Preliminary insights

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1. "Pair Phases" / "Focus phases":
   sometimes the pair interacts with high frequency
   - short phases (0,5 - 3 minutes)
   - happens at varying intervals

2. Driver and Observer are <u>not</u> on different levels of abstraction

3. The driver often performs "think aloud"

4. Ignoring the partner is not rare

PP: How does it work? Status and further work

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- We have recorded a number of PP sessions
  - 2 sets of student pairs doing (one set each for two tasks)
  - individual sessions from a number of companies (professional programmers)
  - interviews with professional programmers after sessions

- Almost finished: Description of PP basic process concepts
  - See figure above
- We will next look at individual types of phenomena
  - "focus phases", strategic and tactical decisions, misunderstandings, knowledge transfer, etc.

Interested? Talk to us!

- We will extend the investigation to distributed contexts:
  - Saros, see subsequent slides

Saros: Distributed Party Programming

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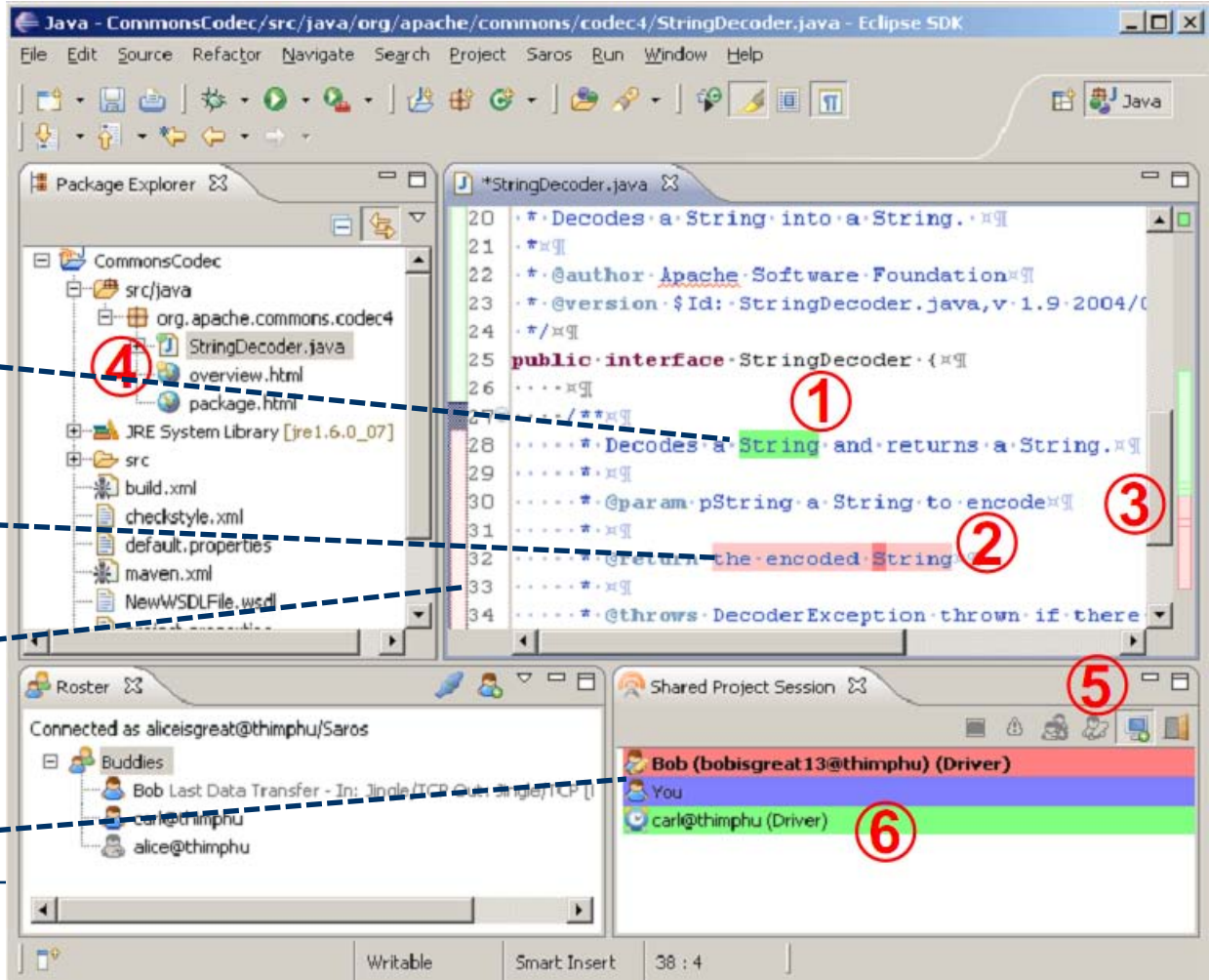
- Saros is an Eclipse plugin that couples multiple Eclipses remotely for real-time collaborative editing
  - with awareness functionality

Highlighted by participant 3

Recently written by participant 1

Current activity of participant 1

Session participants



Saros: Usage modes

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- Saros allows Distributed Pair Programming and
- Supports multiple Observers
  - useful for **joint reviews** or for **training newbies**
- Supports multiple Writers
  - useful for **Side-by-Side programming**
  - useful for **Distributed Party Programming (DPP)**:
    Multiple (say, 5) developers "hang around" in the same session,
    each doing their own development,
    and quickly helping each other out when needed

- Plenty of research to be performed on DPP
  - Do developers accept this? What awareness info is needed?
    How useful is the mode? How to use it well?
- Plenty of Saros development to be performed
  - Complete VoIP, sketching, screen sharing, …
  - Improve architecture, robustness, automated testing, …

Interested?
Talk to us!

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
  - can be extended to remote settings, loose coupling, N persons
- 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
- More research is needed
  - We are also extending the research to distributed settings
    - Development of Saros plugin
    - Corresponding evaluation research (in OSS projects and in industry)
  - Talk to AG SE if you consider participating in such research

Thank you!