Course "Softwareprozesse"

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

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."

Driver/observer does not really work like this
Related methods

**Distributed Pair Programming (DPP):**
- The partners are not physically in the same room and use a separate computer each
  - [http://www.saros-project.org](http://www.saros-project.org) (Saros, see last few slides)
- Their interaction is supported by a collaborative editor and audio conferencing, perhaps also 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)

Distributed Party Programming (DPP):
- work style like Side-by-Side programming
- but with perhaps more than 2 participants (up to ~5)
  - only possible with appropriate tool support
Ways towards understanding PP: Blackbox perspectives (quantitative)

Independent variable
(Primary collaboration)
- Individual programming
- Partner programming
- Pair programming
- Team collocation

Dependent variables
(Outcomes)
- Time
- Cost
- Quality
- Information and knowledge transfer
- Trust and morale
- Risk

Context variables

Subject variables
- Education and experience
- Personality
- Roles
- Communication
- Switching partners

Task Variables
- Type of development activity
- Type of task

Environmental variables
- Software development process
- Software development tools
- Work space facilities

source: [GalAriDyb03]

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

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

- 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)
## Results

### Comparison of Individual and Team Measurements

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

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

Indiv. take 41% longer, but difference is not significant 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

- **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?

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 Jasiński, 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])
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, Müller and 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?

- 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 ("truck number")
    - 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 quantitative empirical results are known
PP: Benefits from learning from one another?

- 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 very 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 not 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

- Not many specific recommendations are known
  - Ping-Pong Pair Programming is an exception
    - it is also quite extreme
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
  - using SbS/DPP styles etc.
- 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

- **Basic idea:** Look **into** the process
  - Not just at its outcomes: Investigate the PP microprocess

- First understand the **base activities** of the programmers
- Then obtain an **understanding of the total PP process**
  - Perhaps concentrating on only a few aspects at first (e.g. knowledge transfer, strategy, role behavior, work modes)
- Then identify **helpful/unhelpful patterns of behavior**
  - PP behavior patterns and anti-patterns
- Formulate these such as to become a **learnable PP skill**

- To do this, we need detailed data about PP sessions
  - Audio + Video (people and screen activity)
PP: How does it work?

Our research approach (2): The Data
PP: How does it work?
Our research approach (2)

• We need a mix of data sources to satisfy all our requirements:
  • Field observations of professional programmers allow to develop *relevant* theories
  • Laboratory observations (e.g. of students) allow to see *multiple instances of equivalent problem-solving* for comparison

• We have recorded several dozens of PP sessions
  • student pairs in the laboratory
  • sessions from a number of companies (field sessions of professional programmers)
  • interviews with professional programmers after sessions (reflection)
PP: How does it work?
Our research approach (3)

Data analysis using the Grounded Theory Methodology (GTM):

• GTM: the *constant comparative method* of qualitative research
  • It leads to theories that are fully grounded in data
  • Its main prerequisite is *theoretical sensitivity*
  • Its main processes are *memo-writing, open coding, axial coding, selective coding, theoretical sampling*
  • Supported by appropriate software (e.g. ATLAS.ti)

• Our goals:
  1. Form a appropriate vocabulary (~open coding)
  2. Identify helpful and damaging behaviors (~axial coding)
  3. Describe them as **patterns** (~selective coding)
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 initially
   - For challenging vagueness and enforcing consistency

3. It is helpful to use structured code names
   - person.verb_object: "P1.propose_step", "P2.explain_completion"

- We use the following perspective:
  - directly observable actions only
    - in particular verbal communication
- We avoid anything requiring subjective judgement, such as
  - attribution of "helpful"/"unhelpful" to individual actions
  - attribution of emotions (happy, annoyed, surprised, focused, ...)
PP: How does it work?
Types of verbal actions found

<table>
<thead>
<tr>
<th>product-oriented concepts</th>
<th>process-oriented concepts</th>
<th>universal concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>anneed_design</strong></td>
<td><strong>amend_step</strong></td>
<td><strong>explain_gap_in_knowledge</strong></td>
</tr>
<tr>
<td>Extend a given proposal regarding the structure and content of the program without rejecting the proposal.</td>
<td>Extend a given proposal regarding the next tactical work step without rejecting the proposal.</td>
<td>Verbalize that certain knowledge is not possessed by either member of the pair.</td>
</tr>
<tr>
<td><strong>ask_design</strong></td>
<td><strong>ask_step</strong></td>
<td><strong>agree_gap_in_knowledge</strong></td>
</tr>
<tr>
<td>Ask for a concrete proposal regarding the structure and content of the program.</td>
<td>Ask for a concrete proposal regarding the next tactical work step.</td>
<td>Signal agreement with a given gap in knowledge.</td>
</tr>
<tr>
<td><strong>challenge_design</strong></td>
<td><strong>challenge_step</strong></td>
<td><strong>explain_completion</strong></td>
</tr>
<tr>
<td>Reject a given proposal regarding the structure and content of the program and make an alternative proposal instead.</td>
<td>Reject a given proposal regarding the next tactical work step.</td>
<td>Make a statement regarding the degree of completion of the current tactical work step.</td>
</tr>
<tr>
<td><strong>agree_design</strong></td>
<td><strong>agree_step</strong></td>
<td><strong>agree_standard_of_knowledge</strong></td>
</tr>
<tr>
<td>Signal agreement with a given proposal regarding the structure and content of the program.</td>
<td>Signal agreement with a given proposal regarding the next tactical work step.</td>
<td>Ask the partner for his/her level of knowledge with respect to a certain topic.</td>
</tr>
<tr>
<td><strong>decide_design</strong></td>
<td><strong>decide_step</strong></td>
<td><strong>challenge_completion</strong></td>
</tr>
<tr>
<td>Select one from among several alternative proposals regarding the structure and content of the program.</td>
<td>Select one from among several alternative proposals regarding the next tactical work step.</td>
<td>Make a statement regarding the degree of completion of the current tactical work step and make an alternative statement.</td>
</tr>
<tr>
<td><strong>disagree_design</strong></td>
<td><strong>disagree_step</strong></td>
<td><strong>challenge_requirement</strong></td>
</tr>
<tr>
<td>Reject a given proposal regarding the structure and content of the program without making an alternative proposal.</td>
<td>Reject a given proposal regarding the next tactical work step without rejecting it.</td>
<td>Reject a given proposal regarding the strategy or work plan and make an alternative proposal instead.</td>
</tr>
<tr>
<td><strong>remember_requirement</strong></td>
<td><strong>amend_strategy</strong></td>
<td><strong>challenge_strategy</strong></td>
</tr>
<tr>
<td>Remind the pair of a given (pre-specified) functional or non-functional requirement of the program.</td>
<td>Extend a proposed strategy or work plan without rejecting it.</td>
<td>Signal agreement with a given proposal regarding the strategy or work plan.</td>
</tr>
<tr>
<td><strong>challenge_requirement</strong></td>
<td><strong>ask_strategy</strong></td>
<td><strong>challenge_state</strong></td>
</tr>
<tr>
<td>Reject a given or proposed requirement and propose an alternative one instead.</td>
<td>Ask for a concrete proposal regarding the strategy or work plan to be chosen.</td>
<td>Signal agreement with a statement regarding the degree to which the current strategy or work plan has been worked through.</td>
</tr>
<tr>
<td><strong>propose_requirement</strong></td>
<td><strong>amend_state</strong></td>
<td><strong>challenge_hypothesis</strong></td>
</tr>
<tr>
<td>Propose one or several alternative program characteristics that should be considered to be a requirement.</td>
<td>Propose one or several alternative strategies or work plans.</td>
<td>Reject the content of a verbalized insight or conjecture and suggest an alternative one.</td>
</tr>
<tr>
<td><strong>mumble_step</strong></td>
<td><strong>say_off_topic</strong></td>
<td><strong>challenge_hypothesis</strong></td>
</tr>
<tr>
<td>Make an incomprehensible utterance (highly fragmented or acoustically unclear).</td>
<td>Make an utterance that has nothing to do with solving the programming task.</td>
<td>Declare transferred knowledge as fully, partially, or potentially wrong by opposing it with one’s own knowledge.</td>
</tr>
<tr>
<td><strong>disagree_strategy</strong></td>
<td><strong>disagree_step</strong></td>
<td><strong>challenge_hypothesis</strong></td>
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<tr>
<td>Reject a given proposal regarding the strategy or work plan without making an alternative proposal.</td>
<td>Reject a given proposal regarding the next tactical work step.</td>
<td>Declare transferred knowledge as fully, partially, or potentially wrong without explaining why.</td>
</tr>
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<tr>
<td>Signal agreement with a given proposal regarding the strategy or work plan.</td>
<td>Signal agreement with a given proposal regarding the next tactical work step.</td>
<td>Reject a given hypothesis or conjecture.</td>
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<td><strong>challenge_hypothesis</strong></td>
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<td>Reject a given proposal regarding the strategy or work plan and make an alternative proposal instead.</td>
<td>Reject a given proposal regarding the next tactical work step.</td>
<td>Propose an extension to the current HCI or HEI activity.</td>
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</tr>
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<td><strong>propose_strategy</strong></td>
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</tr>
<tr>
<td><strong>propose_todo</strong></td>
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</tr>
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<td>Reject a given proposal regarding the strategy or work plan without making an alternative proposal.</td>
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"The HHI base concepts"
PP: How does it work? 
Preliminary insights (1)

1. There is a PP skill that is different from programming skill

2. Driver and Observer are not on different levels of abstraction
   - More tactical than strategic behavior

3. There are many more roles than just Driver/Observer
   - e.g. Watchman, Spokesperson, Task Expert, Backseat Driver
   - no "complete" set of roles is yet known

4. The Driver often performs "think aloud"

5. Disengagement threatens ill-working PP
• Topics discussed in the reflections:
  • Distribution of labor
    • E.g.: Only one programmer determined the tactical orientation
  • Lack of strategic orientation
  • Knowledgeable in different areas
  • Increasing lack of concentration
  • Disparate session goals or attitudes
    • E.g.: fast vs. clean

• Preliminary insights:
  • Discussion can lead to change in behaviour
    • E.g.: Both programmers determine the tactical orientation
    • Open question: How to achieve this reliably?

• Reflections help the researcher to understand the context
PP: How does it work?
Status and further work

- Finished: Book on PP basic process concepts
  - HHI concepts, HCI/HEI concepts, instructions for use

- We will next look at individual types of phenomena
  - knowledge transfer, roles, strategic and tactical decisions, misunderstandings, disagreements, interruptions, etc.
  - For instance, capable pairs tend to use a certain order of question types to query difficult issues (the "clarification cascade")

- We are extending the investigation to distributed contexts:
  - see subsequent slides
Saros is an IDE plugin (Eclipse, IntelliJ IDEA) that couples multiple IDEs remotely for real-time collaborative editing.

Session participants

View & highlight by participant 2

Recently written by participant 2

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Saros: Usage modes

- Supports multiple Observers
  - useful for joint reviews or for training newbies

- Supports multiple Writers
  - useful for **Side-by-Side programming**
  - perhaps also useful for **Distributed Party Programming:**
    - Multiple (say, 5) developers "hang around" in the same session, each doing their own development, and quickly helping each other out when needed
  - useful for **Distributed Pair Programming:**
    - First research result:
      Distributed-Pair Programming (DPp) is not just Distributed Pair-Programming (dPP)
    - Rather, capable pairs make judicious use of concurrent editing and viewing to make the process more fluent.

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Saros: Research and Development

- Plenty of research to be performed on DPP
  - Which developers accept this? What awareness info is needed?
    When is it most useful? How to use it well?

- Plenty of Saros development to be performed
  - Sketching, integration of 3rd party communication SW
  - Improve architecture, robustness, automated testing, ...

Interested? Talk to us!
Summary

• Pair Programming (PP) is the joint production of artifacts by two equally active programmers with fully shared ownership
  • using one computer, often only one keyboard
  • can be extended to remote settings, loose coupling, N persons

• PP has a number of potential benefits
  • for productivity, correctness, design quality, concentration, information flow, learning, truck factor
  • Empirical results regarding productivity are somewhat mixed
  • Empirical evidence regarding the other benefits is scarce, because measuring them is very difficult

• Much more research is needed
  • Describe and operationalize PP skill (via behavior patterns)
  • Must use real industrial pairs working on real tasks
  • Both local and distributed settings
Thank you!