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A Coding Scheme Development Methodology Using Grounded Theory for Qualitative Analysis of Pair Programming

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Contents

- We do talk about:
  - In brief:
    - research in Pair Programming (PP) done up to now
    - our research
    - basics of (plain) Grounded Theory (GT)
    - our data (video)
  - Problems with plain GT on rich video data
  - Four practices to avoid those problems:
    - Practice 1: Perspective on the data
    - Practice 2: Concept name syntax rules
    - Practice 3: Meta-model
    - Practice 4: Pair coding
  - Use of the practices: an example
- We do not (really) talk about:
  - Concrete results of our PP research
    - Only to demonstrate the usefulness of our practices

Pair Programming: Description

- In PP
  - two programmers jointly produce one artefact (design, algorithm, code, etc.).
  - [...]
  - One partner is the *driver* and has control of the pencil/mouse/keyboard [...]
  - The other person (*observer*) continuously and actively observes the work of the driver ...
  - The roles of driver and observer are [...] switched between the pair [...]
  - [...]

(Williams, Kessler, and Cunningham (2000))

Pair Programming: research done up to now

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- PP has been subject of many empirical investigations
- Most of them are quantitative. They regard the underlying process of PP as a kind of *black box*
  - Performance
  - Error rate
  - Programmer satisfaction etc.
- The results of this research are often contradictory
  - Most likely these differences are caused by differences in moderator variables (*type of task* etc.)

Pair Programming: our research

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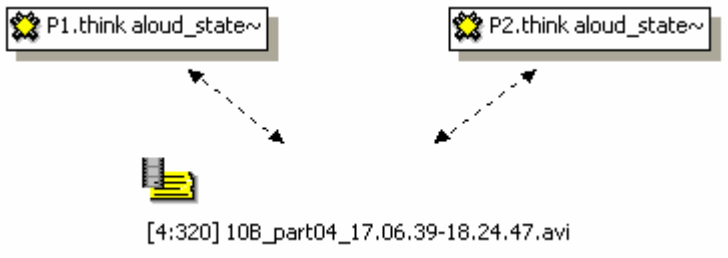
- Our overall goal is to understand PP in such a way that we can advice practitioners how to use it most efficiently
- The only way to obtain this understanding is *to look into the black box*
  - Understanding the mechanisms at work in the PP process
  - This understanding must first be gained in qualitative form
  - Since we do not know much yet, the investigation has to start exploratorily.
- We started with an investigation based on GT
- We used rich sets of data (audio, video, screen capture)

Basics of Grounded Theory (1)

- GT (Glaser/Strauss 1967):
  - Qualitative data analysis approach
  - Uses hardly any prior assumptions nor predefined terminology
  - Produces a *theory* that describes interesting relationships between *phenomena* (situations, events etc.)
    - The phenomena are represented by abstract *concepts/codes*
  - Some central aspects of GT according to Strauss (1995):
    - ***Theoretical coding***: Codes are theoretical, not just descriptive; they have explanatory value for the phenomena
    - ***Constant comparison***: Observed phenomena are compared many times in order to create concepts that are precise and consistent

Basics of Grounded Theory (2)

- We use a variant of GT described by Strauss/Corbin
  - It suggests three (partially parallel) activities. Two of them are:
    - ***Open coding***:
      - Describing the data (phenomena) by means of conceptual codes (derived directly from the data)



    - ***Axial coding***:
      - Identifying relationships between the concepts
      - Strauss/Corbin suggest a concrete set of relationships to be checked for. They call it a *paradigmatic model:*

context

causal condition → *phenomena* → *participant's strategies* → *consequence*

Data used for our analysis of PP (1)

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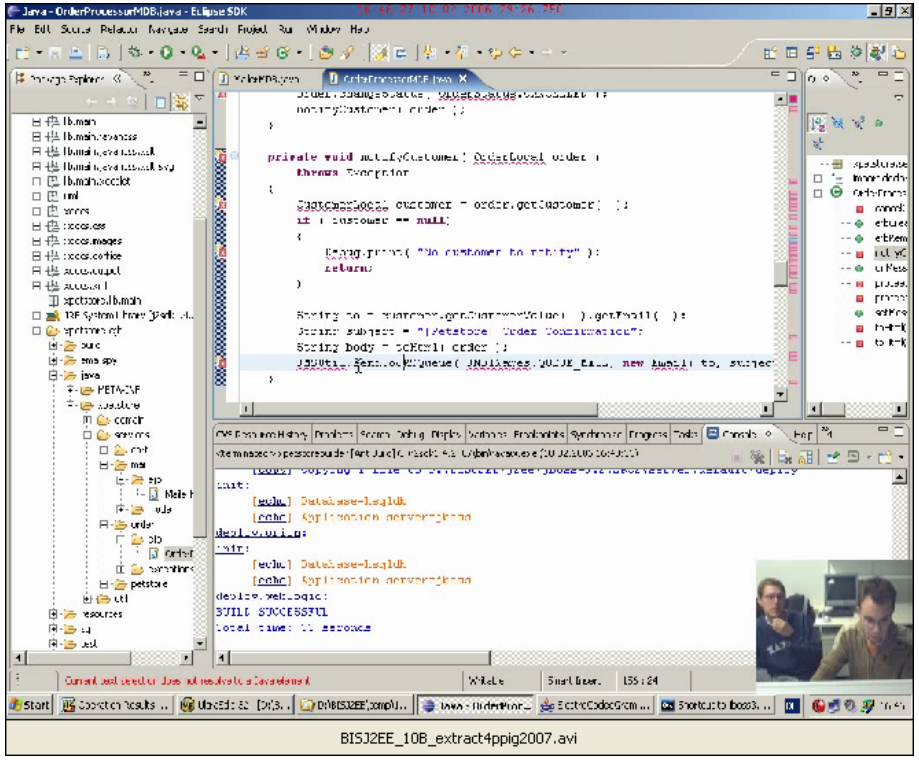
- Origin of the Data
  - Experiment at the end of a course on enterprise information systems and J2EE
  - Participants: seven pairs of graduate students
  - Task: Extension of an existing web shop application
    - Required broad passive J2EE knowledge about JMS, JNDI, and JBoss application server
    - Non-trivial: only three pairs were completely successful
- Data capturing procedure
  - Audio recording
  - Frontal-perspective video of the programmers
  - Full-resolution screen recording capture (all computer activities of the programmers)

Data used for our analysis of PP (2)

- All three recordings are unified into a single, fully synchronized video:



- We decided to work on video directly (transcription was not practical)
  - Too much potentially relevant information (e.g. in the screen recording)
- We chose a QDA-Software that allows creating annotations to video.

Our initial attempt of using GT (1)

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- Initial attempt: Open coding in the manner suggested by Strauss/Corbin
- Short-term goal: Characterizing the activities occurring during PP

- This approach generated 194 different concepts, but
  - almost complete confusion and
  - hardly any results

- We recognised the following problems:
  1. No predefined focus
     - No criteria for selecting which observations to code or to ignore
     - We where overwhelmed by the data
  2. No predefined granularity
     - No prior decision on the level of detail
     - We produced codes on different levels of detail, which where difficult to delineate against one another subsequently
       - E.g.*: handle problem* vs. *test defect fix*
  3. No predefined level of acceptable subjectivity
     - GT does not provide a criterion for deciding where „grounded in data“ ends and „wishful thinking“ begins
     - We mixed objective-descriptive and subjective-evaluative attitudes for selecting codes
       - E.g.: *uses documentation* vs. *gains knowledge of detail*
       - Hard to decide which one to use in a particular case
  4. Lack of concept grouping

Our initial attempt of using GT (2)

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- With this understanding we stopped this mode of investigation completely
- We redesigned the coding procedure.
- The result of the redesign were a number of heuristic and intertwined practices (the heart of this presentation)
  - Practice 1: Perspective on the data
  - Practice 2: Concept name syntax rules
  - Practice 3: Meta-model
  - Practice 4: Pair coding

Practice 1: Perspective on the data

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- To start the analysis, Strauss/Corbin only suggest to formulate an open and wide question
  - They provide no guidelines/no criteria
- In contrast, we suggest to formulate a so called *perspective*
  - This perspective can be defined by answering the following questions:
    - Q1: In which respects do you expect the data to provide insight?
    - Q2: What kinds of phenomena do the researchers allow themself to identify in the data?
    - Q3: What type of result do you want the analysis to bring forth?
  - Three reasons why a perspective used for analysis be defined before starting:
    - To avoid drowning in detail
    - To provide constancy in the criteria used for creating and assigning concepts
    - To focus attention on the most relevant aspects

Practice 1:
Perspective on the data: Question 1

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- Q1: In which respects do you expect the data to provide insight?
  - Q1 asks not what you expect to find, only in what respect you expect to find *something*.
    - Acts as an attention filter
  - E.g. in the case of our investigation:
    - The data/results should help understanding what activities dominate PP and how they are relate

Practice 1: Perspective on the data: Question 2

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- Q2: What kinds of phenomena do the researchers allow themselves to identify in the data?
  - Q2 provides the mechanism for systematically bounding the nature and amount of subjectivity during the process of coding
    - Strongest restriction: only concepts that express directly observable phenomena (behaviouristic (stimulus/response) research perspective)
    - Weaker restrictions allow:
      - concepts referring to unobservable processes (e.g. attitudes or thinking processes)
      - concepts that involve prediction (such as „helpful for reaching goal X“)
      - concepts expressing moral judgement (good, bad)
  - E.g. in the case of our investigation:
    - We were convinced that only the behaviourist perspective would enable us to trust our results

Practice 1: Perspective on the data: Question 3

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- Q3: What type of result do you want the analysis to bring forth?
  - Do you want to produce a full conceptual theory?
  - Or just a conceptual structure (system of categories)?
  - Or even simply a coding scheme?
  - E.g. in our case, the goal was just to produce a coding scheme
    - We felt we knew too little about the internals of PP

Practice 2:
Concept name syntax rules (1)

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- Strauss/Corbin: No guidelines for concept names
- Our experience: freely chosen concept names turned out to be highly variable and hence
  - difficult to understand
  - difficult to remember
  - difficult to compare
- As a remedy we developed a structured naming scheme

Practice 2:
Concept name syntax rules (2)

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```
code                = <actor>.<description>
description         = <verb>_<object>[_<criterion>]
```

- Examples:
  - „P1.ask_knowledge“, „P2.explain_knowledge“
  - Other investigations potentially need other schemes
- Note for GT experts: In plain GT, finding relationships involves axial coding. By practice 2, recording at least some relationships became a benefit of open coding

Practice 2:
Concept name syntax rules (3)

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- When working with the scheme, we observed the following benefits:
  - Concepts will be better understood right at introduction time
  - The syntax facilitates handling and overlooking a large set of concepts
  - Some relationships between concepts are implicitly recorded as well (simplifying axial coding)
  - A concept name *explicitly* represents several aspects at once (simplifying „constant comparison“)
  - It becomes easier to understand where difficulties in delineating one concept against another come from

Practice 3: Meta-model (1)

- By practicing GT, we found some of the terminology and concepts confusing:
  1. GT and our QDA-Software have their own terminology

GT	ATLAS.ti
phenomena	quotations
conceptualization	annotation
concepts	concept/code
properties	concept/code
categories	families
relationships	relationships/relations

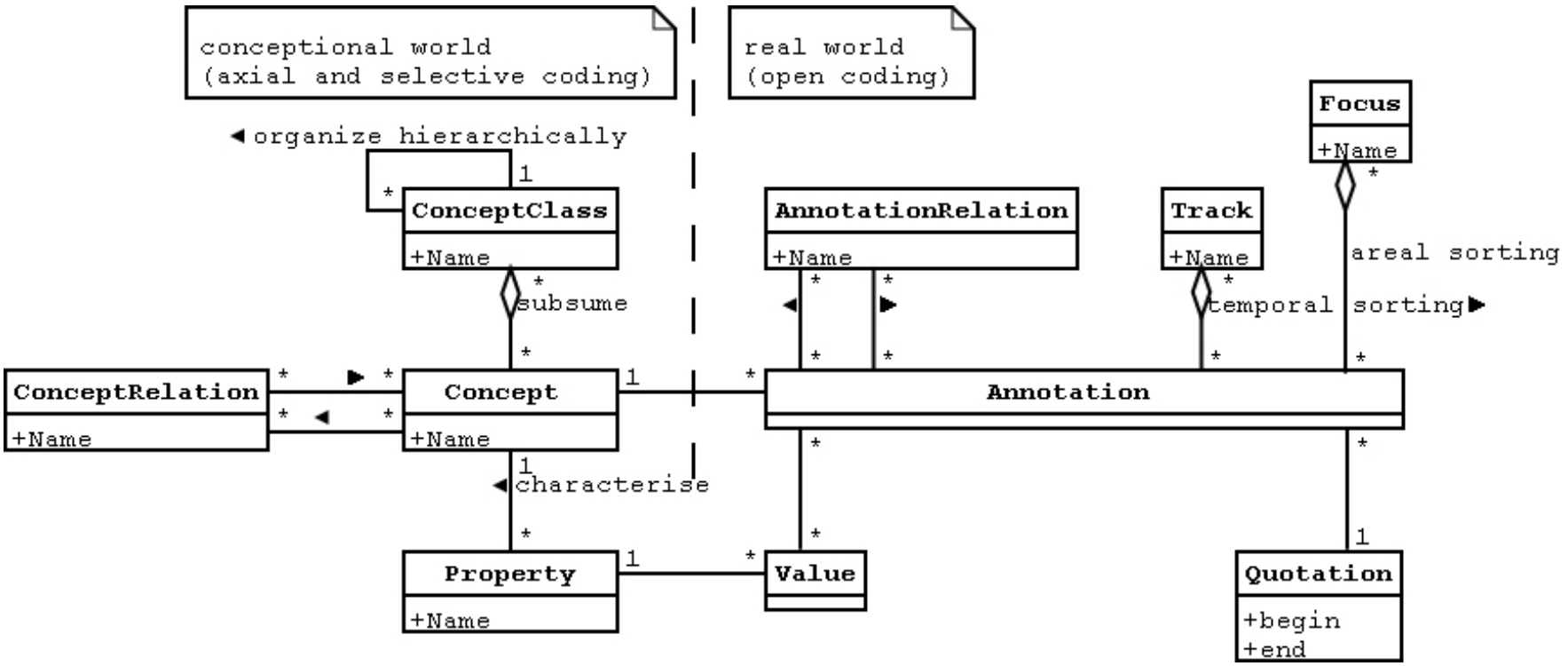
  2. Some of the differences were subtle enough that we misapplied them every once in a while
     - We became confused when we tried to reconstruct what we had meant to express

Practice 3: Meta-model (2)

- These issues prompted us to formulate an explicit meta-model
  - A model of the concepts that describes the structure of analysis *results*
  - A model that acts as a repository of ideas for the analysis *process*

Practice 3: Meta-model (3)

- The meta-model formulated as UML class model:



Practice 4: Pair coding (1)

- Pair coding: all coding work is done by two people working together at one computer
  - Key idea: requiring a consensus of two people for all important decisions. E.g.:
    - Single out phenomena for coding
    - Decide which existing concept to use for coding or when to create a new concept

Practice 4: Pair coding (2)

- We found a number of benefits of a pair compared to a single researcher:
  - Concept definitions become more exact
  - The differentiation between similar concepts becomes more precise
    - It is less likely that a concept slips in that is on a much different level of granularity
  - Remaining concept differentiation problems will not be ignored but rather discussed
  - The perspective on the data (practice 1) is maintained more consistently
  - A larger number of relevant phenomena are detected and encoded

Short example (1)

- Evolutionary history of four concepts of the *think aloud* `ConceptClass`

History of observed phenomena / Actions of the coders	New Concept

• We recognized that the driver verbalized what he was doing
• We made two decisions:
  • Development of two `ConceptClasses` HCI and HHI (meta-model)
  • Postulation of a new concept
  • By the concept naming syntax structure (practice 2) this concept generates a whole `ConceptClass` „to think aloud“
	thinkaloud_activity
	(explains a current computer-operating activity)

• We found a phenomenon that was obviously thinking aloud, but that did not explain computer activity
  • Postulation of a new concept
  • Discussion of the pair coder (practice 4): *thinkaloud_activity* can be used only for the driver and has priority where the other might also be applicable
	thinkaloud_finding
	(states a newly won insight)

• We encountered a programmer‘s explanation of the state of affairs • Postulation of a new concept	*thinkaloud_state* (reflects on the current state of work)

- Soon we found *thinkaloud_state* to exhibit two problems (pair coding):
  1. We had a case where it collided with *thinkaloud_finding* (the finding concerned the state of work)
  2. It designates statements on different levels of abstraction and granularity.

Short example (2)

History of observed phenomena / Actions of the coders	New Concept

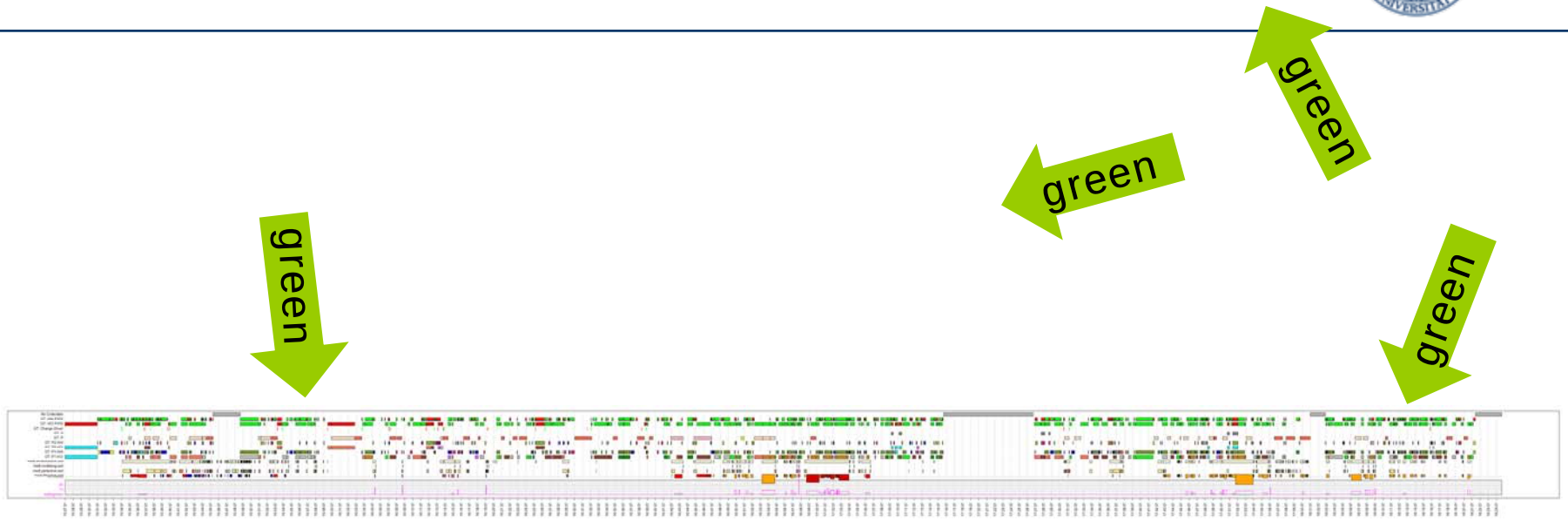
• We solved both problems by using the meta-model (practice 3):
  • Introduction of the `ConceptRelation` „is precondition-of“ from the existing codes
  • *propose step* (suggesting the next step)
  • *propose_strategy* (suggesting many future steps)
  • We postulated:
  • *think aloud_state* had to refer to a previous *propose_strategy*
  • A new concept *thinkaloud_completion* had to refer to a *propose_step*
	think aloud_completion

• We could now discriminate large and small granularity (strategic and tactical)	
• We gained a criterion for when not to use *thinkaloud_finding* (through demarcation to the other two)	

- The example illustrates
  - how open coding naturally leads into axial coding and
  - how the combination of the paradigmatic model with the concept naming syntax (practice 2) can show a way back to open coding

Conclusion

- Conclusion
  - Plain GT on rich video data of PP sessions is not likely to be successful
  - A set of four analysis practices provides a systematic way to hold the analysis problems at bay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Further work

- Some further work:
  - Validation of the coding scheme: encoding of different sessions (participants, tasks,...)
  - Qualitative and quantitative evaluation of the coding process itself
  - Refinement of the coding scheme with respect to particular research applications (e.g. adding properties)
  - Application of the coding scheme to produce actual grounded theories of several aspects

Hypotheses
based on the coding scheme

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- Some Hypotheses based on the coding scheme :
  - No clues that driver and observer so indeed work on different levels of abstraction
  - We have observed what we call pair phases, characterized by a high density of communication acts refering to just one narrow issue
  - We believe that PP is not driven by strategic planning and monitoring.
  - Besides the unavoidable roles of driver and observer, PP sessions apparently tend to implicitly produce a *leader* role as well