



Mair, Carolyn and Shepperd, Martin and Stephens, Mark. (2008). How Cognitive Psychology Can Help Analogy-Based Project Estimation. In: The 19th UK Software Metrics Association Annual Conference on Software Measurement, 15-16 October 2008, London, UK.

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How Cognitive Psychology Can Help Analogy-Based Project Estimation

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Research Project

“A Cognitive Perspective on Analogy-based Project Estimation”

Aim: to investigate cognitive processes of software professionals using CBR tools to develop more effective support for estimators.

Funded by UK Government (EPSRC) in collaboration with EDS (2008-9).

Biographies (1)

Dr Carolyn Mair is a Senior Lecturer in Psychology at Southampton Solent University. She lectures in Cognitive Psychology and Psychobiology and her research interests are in cognitive processes.



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Biographies (2)

Prof Martin Shepperd holds the Chair of Software technology at Brunel University. His research interests include software engineering and project cost modelling.

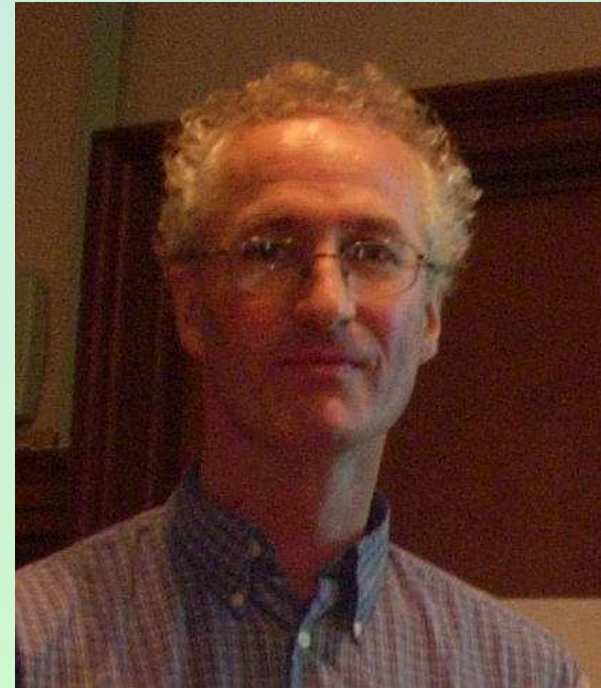
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Biographies (3)



Dr Mark Stephens works for global outsourcer, EDS, as part of their Application Services Global Metrics Group. He has recently been involved with Estimation improvement initiatives, but has a keen interest in all metrics related disciplines.



Agenda

1. Scene setting
2. How cognitive psychology can help
 - Individual differences
 - Outline of our methodology
3. Summary

1. Scene setting

- Project cost (typically effort) estimation is an example of infrequent, high-value problem solving
- Lack of knowledge to produce immediate solution
- Typically humans use past experience when solving problems

Defining the Problem

- We want *accurate* cost and schedule predictions for software projects at an *early* stage
- Repeatability (defined process)
- Rationale for prediction

But ...

- Dealing with complex, dynamical and open systems that are not well understood
- Trade-offs and constraints
- Attempts to find simple (or complex) predictive models not generally successful

Why use Expert Judgement?

Most widely used estimation technique

No consistently 'best' automated prediction system

Lack of historical data

Need to 'own' the estimate

Experts plus ... ?

Problems with Expert Judgement

Objectivity

Repeatability

Recall /awareness

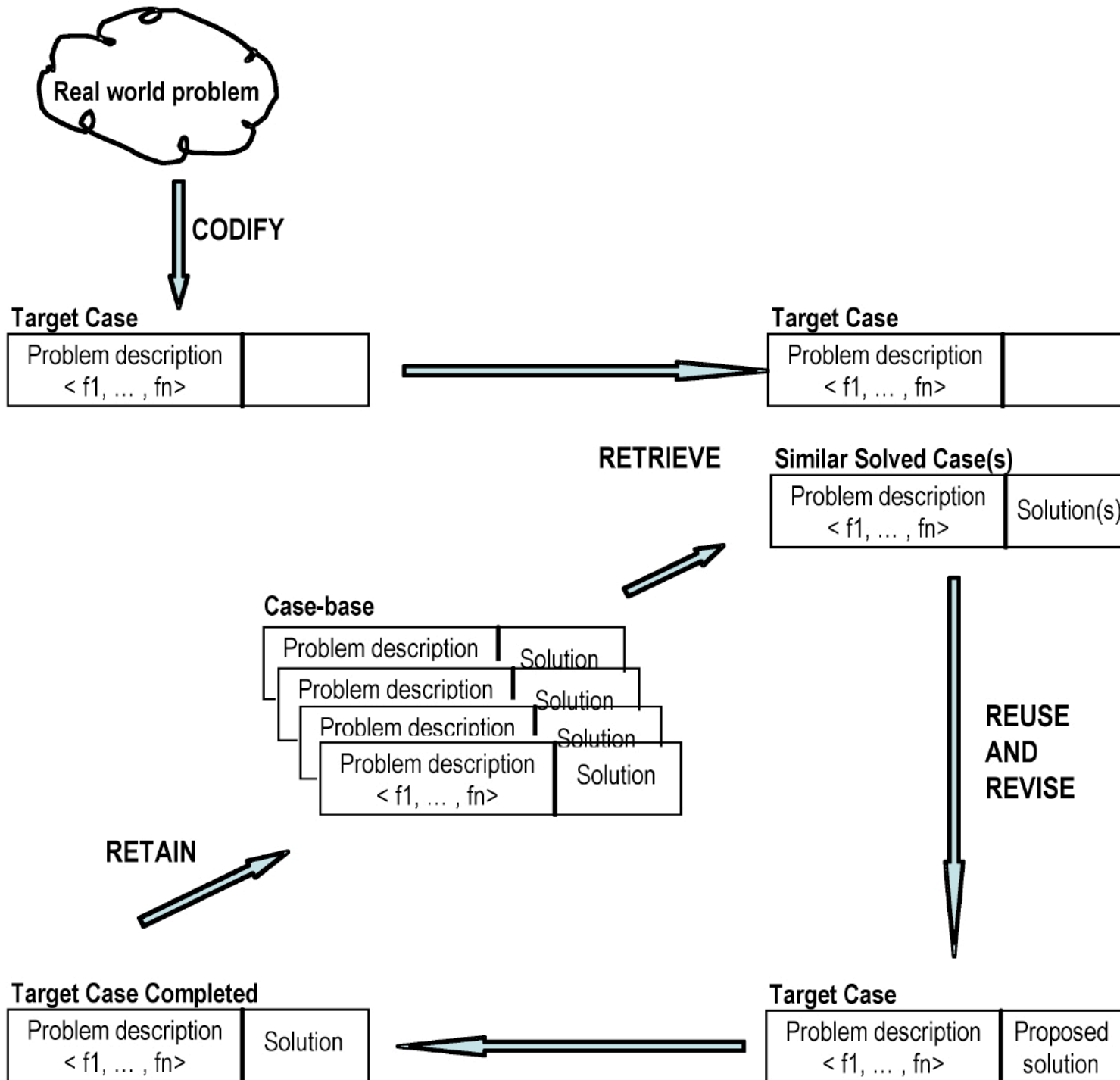
Not enough experts!



Source: Leading Answers – Agile estimation

Analogical Reasoning (automated as CBR)

- Automated retrieval of similar but not identical cases (projects)
- Applied with *some* success to project estimation (e.g. BT, Siemens)
- Combine with expert



So what are we researching?

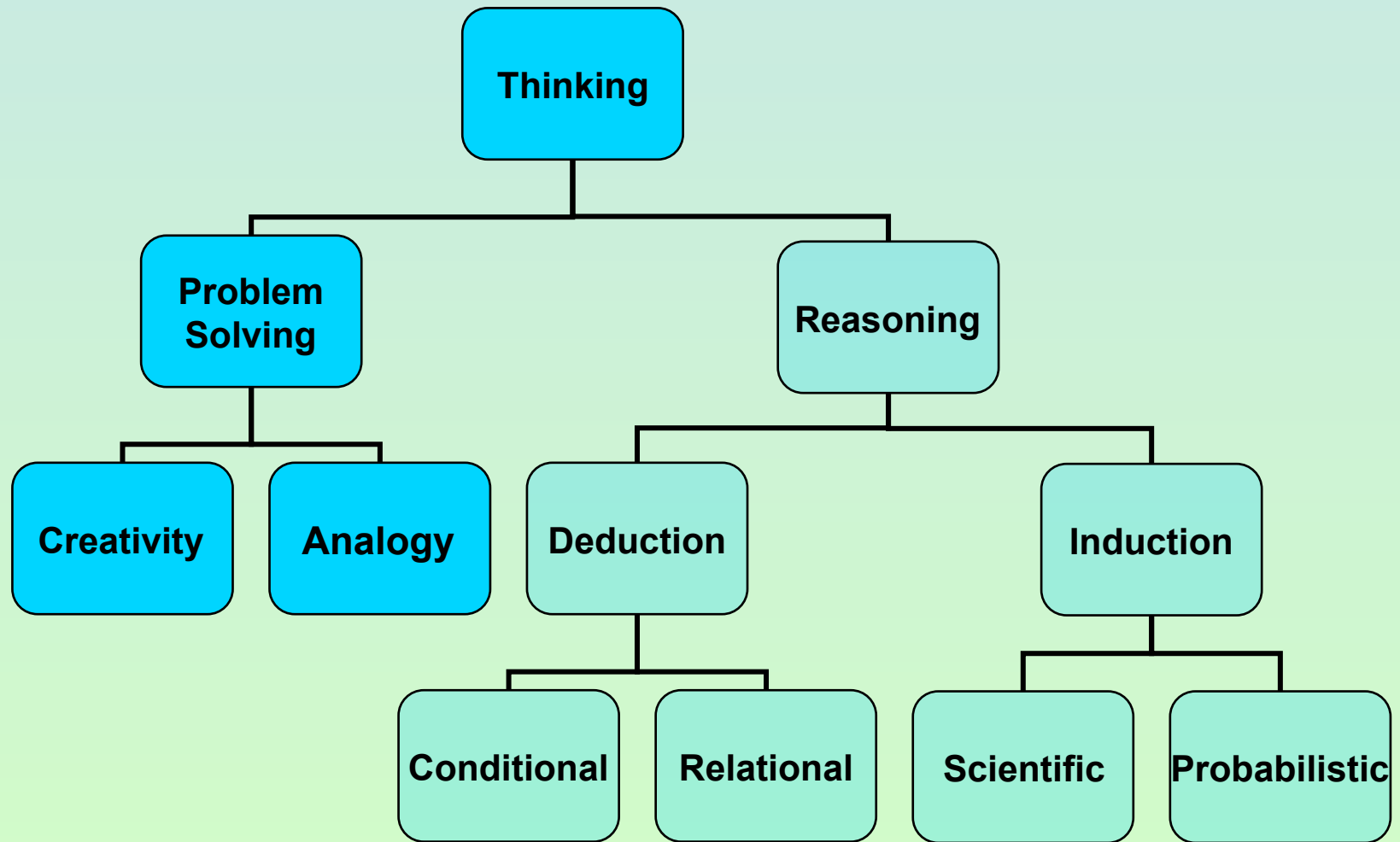
- Why is project estimation not accurate?
- Expert judgement problematic
- CBR problematic
- Maybe experts + CBR = more accurate?

- Human problem-solving no longer black box
- Cognitive science

2. Cognitive psychology theories of problem solving

- Many theories
- To what extent are these theories applicable to experts using CBR in 'real world'?

Thinking hierarchy



Adapted from Eysenck and Keane

“A problem is any given situation that differs from a desired goal”

1 Well-defined problems

- clear goal state
- possible algorithmic solution
- finite set of operators (rules)

2. Ill-defined problems

- not clearly definable, but involve sub-problems that can be well-defined
- involve creativity

Analogical Problem-solving

Reasonable evidence for superficial, structural, and procedural similarity between past and current problems, but...

- similarities between problems in everyday life less obvious
- people typically choose superficial rather than structural similarities
- individual differences in problem solving strategies and personality traits

Research methodology

1. Conduct systematic review and analysis of empirical studies of professionals using analogy based techniques
2. Observe professionals using CBR tool (archANGEL) to solve real-world software engineering problems
3. Adopt Grounded Theory (GT) approach to determine a theoretical framework for understanding and improving the use of CBR tools when predicting project effort
4. Analyse task performance data in light of existing data
5. Generate recommendations for improved tool support and processes
6. Determine a new research agenda with international research groups and practitioners

The problem domain

- Recent interest in CBR, as a knowledge management tool, has resulted in a large literature emphasising algorithmic approaches typically used for well-defined problem solving, but...
- Software project managers solve non-trivial or ill-defined problems using other cognitive strategies (e.g. creative thinking)
- Personality impacts cognitive processes, thus problem solving ability and strategy

Added value: cross-disciplinary

Merge knowledge from cognitive psychology and computer science to investigate cognitive aspects of software engineering when using analogy-based tools to improve prediction effectiveness.

Problems with analogical problem solving

- Gestalt psychologists: problem solving involves 'restructuring' (e.g. considering how the problem is represented mentally and how the representation would need to be restructured in order to find a solution)
- To reach solution, we could use 'reproductive thinking' (using past or analogous experience), but...
- 'Fixation' can obstruct satisfactory problem solving if habit restricts novel and creative thinking
- Erroneous or suboptimal solutions result from inaccurate interpretation or representation of the problem
- Potential hazard for analogical problem solving

Gentner et al.'s structure mapping theory of analogy

- Analogies are concerned with relations rather than features
- Analogy maps knowledge from one domain to another through a system of relations in place in both domains
- Comparison promotes analogous problem solving and even when relations are similar, but not identical, representation processes will find partial match
- Potentially important since computer science emphasis has been upon feature similarity

Analogy, "*the core of cognition*" (Hofstadter, 2001)

- Analogical problem solving refers to cognitive process of transferring information from particular source to particular target
- Significant role in problem solving, decision making, perception, memory, creativity, emotion, explanation and communication

3 steps of analogical problem solving (Gick and Holyoak, 1980)

1. Noticing analogical connection between source and target
2. Mapping corresponding parts of onto each other
3. Applying the mapping to generate a parallel solution to the target problem

Why experts use analogy?

- Reduce memory load (using schemata, analogy structures)
- Interact with automated solutions (e.g. CBR tools) to facilitate handling of familiar aspects of problem, and to free cognitive capacity for its novel aspects
- Primary focus of analogical reasoning has been on algorithmic aspects of analogy and similarity metrics
- Sparse published work on cognitive processes in software engineering domain
- Investigated analogy as a means of specification reuse using think-aloud protocol (Sutcliffe and Maiden, 1991)

A second dimension

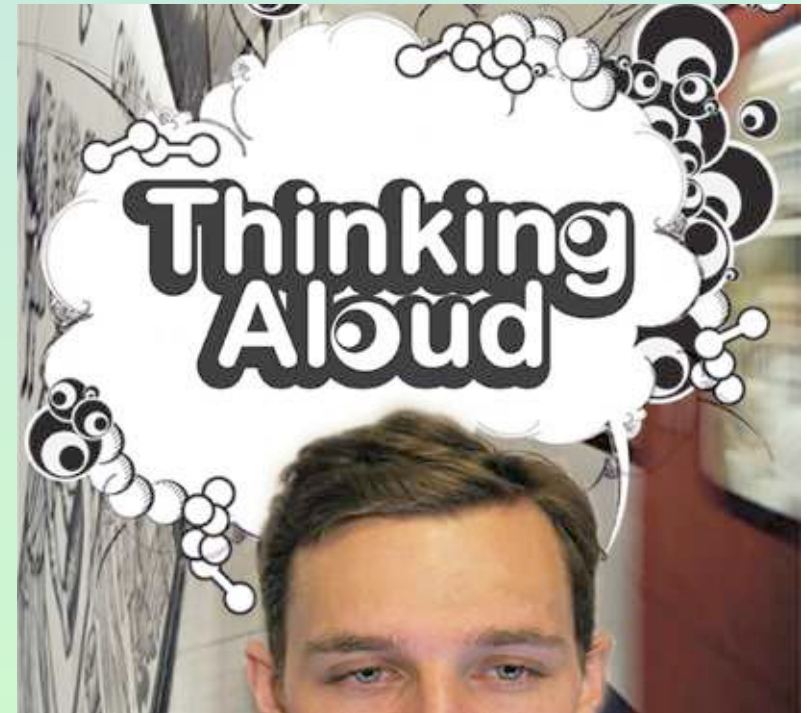
- Relationship between personality, cognitive style and problem solving performance in the workplace
- EPI

Methodology: overview

- Grounded Theory
- Pilot investigation
- Identify suitable prediction tasks which
 - are realistic, but of manageable scale
 - have some familiarity
- Populate case base so CBR system (archANGEL)
- Contrast analogy with reference approach (e.g. simple top-down method such as work breakdown structure)
- Interview, observe + think-aloud
- Participants: expert estimators from EDS, UK recruited using convenience sampling

Methodology: observation

- Familiarise participants with think-aloud method
- Video record for verbal transcript and visual record of interaction with CBR tool
- Semi-structured interviews pre and post problem solving session to collect attitudinal and biographical data



Source: JD Gordon

3. Summary

- To return to our original question: why doesn't analogy-based estimation always work?
- This project is based on the idea that we shouldn't neglect the professionals using the tools and techniques developed by computer scientists
- So we have commenced exploring application of cognitive psychology theories
- Plan to study professionals carrying out real prediction tasks *in situ*

Intended outcomes

This project is working towards

- Improved understanding, and utilization, of analogy-based project estimation tools (CBR)
- Recommendations for more effective CBR tools
- Follow up project to develop tools based on knowledge and evidence from Cognitive Science.