Designing technical action research, and generalizing from single cases

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1. What is TAR?
2. Logical structure of TAR
3. Generalizing from TAR
4. Summary
1. What is Technical Action Research?
What is Technical Action Research?

• Example
  – Researcher develops a technique to assess confidentiality risks in an IT architecture
  – She applies it to a problem that a company has ...
  – producing an advice to the company ...
  – and drawing lessons learned about the method

• She served two goals:
  – The company’s goal is to assess confidentiality risks
  – The researcher’s goal is to learn something about her method
What is Technical Action Research?

• The researcher plays three roles:
  – **Designer:** Designing a technique
  – **Helper:** Using the technique to help others
  – **Researcher:** Drawing lessons learned about technique

• The key to a proper methodology for TAR is keeping these roles separate
Contrast with observational study

• Example:
  – Researcher observes one or more agile projects to investigate how requirements are prioritized
  – Avoids influencing the projects
  – Observes, analyzes, concludes lessons learned
• No change goal: The company is not influenced
• Researcher’s goal is to learn about prioritization in agile projects as it is currently happening
• (the resulting knowledge may be useful to the companies)
Contrast with consulting

• Consulting
  – Consultant is paid by client
  – Consultant applies known techniques rather than experimental technique
  – Reusable techniques rather than critical evaluation
  – Aims at helping the client and acquiring repeat business, rather than testing a technique
  – Knowledge dissemination (if any) is internal
Contrast with “classical” action research

• In classical AR, researcher helps client to identify and solve a problem
  – Emancipation of the powerless
  – Learning about their situation

• In TAR, the researcher wants to learn something about a technique by using it to solve a client’s problem
Action Research cycle
(Susman & Evered 1978)
Contrast with AR in information systems

• AR in information systems
  – Identify problem in an organization
  – Jointly search for a solution
  – Implement it
  – Evaluate
  – Specify learning

• TAR is technology-driven, not problem driven
  – The technology may be motivated by a desire to solve a class of problems
  – Not a singlular problem
Why TAR for the client

• Risky project with large chance of non-result

• What is in it for the client?
  – Free consult
  – Potentially useful result
  – Advance knowledge of and experience with new techniques
  – Good relationships with university (PR, HRM)
Why TAR for the researcher

• Researcher developed a technique behind her desk
• Applied it to first to small and then to realistic examples
• Compared with other proposals
• Then what?
  – Students will do as teacher tells: no realistic validation
  – Best way to learn about the technique is to apply it yourself
• Important to scale up from desk to practice
2. Scaling up to practice
• Animals, healthy volunteers, and ill volunteers are used as **models** of arbitrary patients
• Conclusions about the models are generalized to arbitrary patients
• Start with testing of prototype in the lab
• End up with using the artifact in practice
• Start with small samples of comparison, end up with large
• From: "It works in theory" before simulation
  • To "It works in the lab" ....
    • ... via increasingly realistic simulations ...
  • To "It works in practice"
3. Logical structure of TAR
Action Research cycle
(Susman & Evered 1978)
• This conflates two action cycles:
  – Action cycle of client
  – Action cycle of researcher
• Each has a different goal and justification
The engineering cycle

• The logical structure of a rational action is that of the engineering cycle
  – Problem investigation
  – Treatment design
  – Design validation
  – Treatment implementation
  – Implementation evaluation
The rationality of the engineer

• Separating solutions ("treatments") from problems
  – Don’t define the problem as absence of (your) solution
• Acknowledging that there are many solutions
  – Your view is not the only one
• Specifying your action before you act
  – Think before you act
• Justifying your choice of action before you act
  – Comparison, trade-offs
• Evaluating your action after you act
  – You could have been wrong ...
  – Learn from the effects of your action
• Problem investigation
• Treatment design
• Design validation
• Treatment implementation
• Implementation evaluation

Stakeholders, goals, Phenomena, diagnosis, evaluation
Treatment = interaction between artifact and context.

Requirements?
Contribution to goals?
Available treatments?
Design a treatment.

- Problem investigation
- Treatment design
- Design validation
- Treatment implementation
- Implementation evaluation

- Interaction between pill and patient
- Interaction between Software and its Context
- Interaction between method and its context of use
• Problem investigation
• Treatment design
• Design validation
• Treatment implementation
• Implementation evaluation

Artifact & Context → Effects?

Trade-off: Changes in artifact
Sensitivity: Changes in context
Effects satisfy Requirements?
• Problem investigation
• Treatment design
• Design validation
• Treatment implementation $\rightarrow$ Transfer to practice!
• Implementation evaluation
• Problem investigation
• Treatment design
• Design validation
• Treatment implementation
• Implementation evaluation

Stakeholders, goals, requirements?
Phenomena: Artifact & Context → Effects?
Evaluation: Effects satisfy Requirements?
• Example: Extending an enterprise architecture (EA) method with goal-oriented requirements engineering (GORE) manage links to business goals
Problem investigation: Relation between EA and business objectives not known

Treatment design: Extend EA method with GORE techniques (ARMOR)


Implementation: Transfer to practice

Evaluation: Monitor usage

Problem investigation: Goal of EA project?

Treatment design: Plan the project

Design validation: Validate the plan

Execute

EA evaluation EA satisfies client’s goals?
• **Two goals**
  – The client evaluates its redesigned EA against its goals
  – The researcher validates ARMOR against **his** goal

• **Three roles for the researcher**
  – Designing a technique
  – Using it to help a client
  – Learning from it
    • How do we use the client cycle to answer these validation questions?
The empirical research cycle

• This is the engineering cycle applied to one specific goal: Answering knowledge questions
  – Knowledge problem investigation
  – Research design
  – Design validation
  – Research execution
  – Results evaluation
The investigator’s rationality

• Adopted from the engineer
• Applied to knowledge acquisition
  – Ask your questions before answering them
  – Do something (i.e. confront with reality) when answering them
  – Be honest about your uncertainty (“in which ways could I be wrong?”)
  – Justify your answers
- Knowledge problem investigation
- Research design
- Design validation
- Research execution
- Results evaluation
• Knowledge problem investigation
• Research design  →  Survey, observational case, Experiment, Action case, Simulation, ...
• Design validation
• Research execution
• Results evaluation
• Knowledge problem investigation
• Research design
• Design validation
• Research execution
• Results evaluation

Would this really answer our questions?
Risk assessment of doing the wrong thing to answer the questions
• Knowledge problem investigation
• Research design
• Design validation
• Research execution
• Results evaluation ➔ Did this really answer our questions?
  Risk assessment of answering the questions incorrectly
Corresponds to the three roles of the researcher: Designer, researcher, helper.
Action Research cycle (Susman & Evered 1978)
Researcher's Engineering cycle

Problem investigation: Relation between EA and business objectives not known

Treatment design: Extend EA method with GORE techniques (ARMOR)


Researcher’s Empirical research cycle

Research problem: Research question, Unit of study

Research design: Select AR, acquire client & plan cycle

Design validation: Would this answer our questions?

Research execution

Results evaluation: Specifying learning

Now we can see what is ignored in classical AR

Client’s engineering cycle

Problem investigation: Diagnosing

Treatment design: Action planning

Design validation: Validate the plan

Action taking

EA evaluation Evaluating
Practical problem: Specify confidentiality control requirements of an outsourcing client in an SLA.

Problem investigation
*(Section I)* Stakeholders, Goals, Problems, Diagnosis, Criteria C0-C6, Existing solutions

Treatment design
*(Section III)* CRAC++ = CRAC + confidentiality requirements specification

Treatment validation
Q1 Would this work if implemented?
Q2 Trade-offs?
Q3 Sensitivity?

Treatment implementation
Transfer CRAC++ to practice

Implementation evaluation
Evaluate practical experience with CRAC++

Research question: Is the proposed method valid?

Research question investigation
*(RQ1)* Does CRAC++ satisfy criteria?
*(RQ2)* How does CRAC++ compare to alternative treatments?
*(RQ3)* In which contexts is CRAC++ usable?

Research design
Acquire a case

Validate the research design
*(Section VIII)*
- Internal validity
- External validity

Execute the research

Analyze results
Answers to research questions? Explanations?
*(Section VII-A)* RQ1: Goal achievement
*(Section VII-B)* RQ2: Comparison
*(Section VII-C)* RQ3: Generalizability
*(Section VIII)* Validity of answers?

Practical problem: Specify confidentiality requirements of X in a particular outsourcing relation.

Problem investigation
*(Section IV)*
- stakeholders involved,
- organization architecture,
- IT architecture
- goals/problems of the stakeholders,
- criteria to measure goal-achievement

Treatment design
Agree on a treatment plan

Treatment validation
Would this achieve stakeholder goals?

Treatment implementation
*(Section V)*
Perform the plan

Implementation evaluation
*(Section VI)*
Evaluate whether stakeholder goals have been achieved
4. Generalizing from TAR

Discussion
General model of empirical scientific research

Instruments to influence the OoS in a particular way (and no other way)

Entity actually studied by a researcher:
A set of one or more population elements or surrogates for population elements

Instruments to observe the OoS (and avoid influence on OoS)
Generalization

• Inference from observations of the OoS to the population
• Like all non-deductive inferences, it is fallible.
  – Ampliative inference: there is more information in the conclusion than in the premisses
  – The researcher needs to give arguments in favor of conclusion
  – And discuss any reasons why the conclusion could be false (threats to external validity)
Kinds of generalization

• **Statistical inference** is reasoning about samples
  – Make an assumption about population distribution and parameters
  – Predict sample statistic
  – Observations confirm or disconfirm the assumption

• **Case-based inference** is reasoning about cases
  – Observe phenomena in a case
  – Explain in terms of architecture
  – Predict that cases with similar architecture will exhibit similar phenomena
• Statistical inference uses the law of large numbers
  – …. Applied to a population
  – …. Population of what?
  – …. Of similar elements

• Case-based inference uses the similarity
  – …. Similarity of population elements (cases)
  – …. Similarity in what?
  – …. In architecture of population elements (cases)
Model of experimental research

Experimental unit(s) to be treated

Instruments used by researcher to apply a treatment to the object of study

Population of all possible elements similar to object of study

Instruments to observe what happened, e.g. pressure meters, voltmeters, questionnaires, interviews, cameras, a diary, logs, etc.
Model of action research

Instruments used by researcher to help the organization, e.g. teaching materials, software, etc.

Instruments to observe what happened, e.g. a diary, logs, etc.

An individual organization deemed to be representative for a population of unobserved similar organizations
Case-based reasoning

• Reasoning from an observed case to an unobserved case
• Is based on similarity between cases.
• Source in legal reasoning
  – When are two cases “similar”?  
  – What follows from this “similarity”?  
• Also well-known in engineering
  – Test an airfoil in a wind tunnel.
  – Infer how a real airplane with similar shape behaves in the air.
• If cases A and B are “similar” then some observations of A can also be expected to occur in B
  – Must be justified by a theory of similarity.
Example of case-based reasoning

• Researcher designs a “rarity-based” lookup algorithm for distributed hash tables (DHTs).
• The algorithm should improve ability to store and look up larger numbers of service descriptions.
• Service descriptions are relatively small and have many keys.
Simulated context

Stakeholder

• Pick number n according to some probability distribution;
• pick random document;
• pick n terms according to uniform distribution;
• use these as query terms

represents

• Eventual set of queries

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Artefact prototype

Rarity-based DHT lookup

• FreePastry DHT system with 500 nodes
• Java 1.5 lookup implementation;
• Run on DAS-2 distributed supercomputer;
• Limit the number of answers to 50

represents

• Intended implementation

CAiSE 2012, Gdansk

Simulated context

Lookup

P2P network

represents

• Random selection of 100,000 from a set of 260,000 documents with on the average 104 terms, created for IR research

• set of resource descriptions. (Both have Zipf distribution.)
Example (continued)

• What theory of similarity is used in this example?

  *Any implementation of my rarity-based lookup procedure*
  - Running on any P2P network
  - Using any distributed hash table
  - Looking up any set of small documents containing terms in a Zipf distribution
  - According to any query

• will have the same performance in terms of
  - Recall
  - Execution time

• To provide more support for this we need additional validation
  - on extreme cases (more nodes, more documents, more queries)
  - On different systems (P2P network, DHT)
Architectural inference

• How can this inference be valid?
  – Because it is plausible that the mechanisms observed in the observed case will also occur in the unobserved case ...
  – ... because they have similar architecture

• Architectural inference
  – Identify the case architecture
  – Identify the mechanisms by which the case responds to stimuli
  – **Explain** the observations in terms of these mechanisms
  – Conclude that in cases with similar architecture, similar mechanisms will produce similar responses
  – **Provided there are no countervailing mechanisms**
Repeatability

• Like any scientific claim, plausibility must be tested by repeating the research
  – By different researchers
  – Different time and place
  – Different objects of study from the same population
• This rules out any of these factors as relevant similarities
Regularities versus mechanisms

• Uses **statistical inference** to show there are regularities without using any knowledge of underlying mechanisms
  – Statistical claims are about samples from a population of similar elements

• Use **case-based inference** to test the presence of mechanisms
  – Case-based claims are about individuals from a population of similar elements
• Researcher is not representative of intended users
  - Client company is representative of similar companies
  - Service organization, experienced architects, mature EA process are relevant features that impact the effectiveness of ARMOR

• Architects who will eventually use method
• Eventual method description
• Future companies where ARMOR will be applied
• Limited method description
• Company with EA organization

Artefact prototype
Simulated context

Method use

CAiSE 2012, Gdansk
Summary of architectural inference

• Architecture of a case
  – Entities with capabilities
  – Relations of influence

• Mechanism of an architecture
  – The way entities interact when a system stimulus occurs

• Relevant similarities of cases are architectural
  – The case is a sociotechnical system with an architecture
  – Components have capabilities and influence relations
  – People have competencies, devices have specifications, matter has potential to respond
Architectural inference gives us architectural generalizations

- Generalizations are existential ("for some", "for many", "for most"),
- not universal ("for all")
  - There may be exceptions
  - Individual cases have many architectures
  - Components may have many capabilities
  - A stimulus may trigger many interacting mechanisms

- Universality comes at the price of idealization
  - Laws of nature are about an idealized, non-existing universe
  - Point masses (physics), perfect rationality (economics) and Turing machines (computer science)
4. Summary
TAR and design science

• Design science is designing and investigating artifacts
• Characteristic for design science is scaling up to practice
  – Start at the desk,
  – continue in the lab,
  – end up in the field
  – In the field you do TAR and/or statistical field experiments
  – Similar to scaling up in pharmaceutical research
• From: “It works in theory” before simulation

  • To “It works in the lab” …. 

  • ... via increasingly realistic simulations ...

  • To “It works in practice”
Limitations of TAR

• Not always clear which of the many conditions of the case contribute to the effect of the artifact
  – These conditions must be present in other cases too
  – But we may not know what they are
• Competencies of people in the context may have a major influence on effect of artifact
• Manage these limitations by repeating the research
• Technical action research is the validation of an artifact by applying it in a realistic case

• The technical researcher is
  – a designer
  – a helper
  – a researcher of knowledge questions

• Generalize by identifying architecture and mechanisms