A Nested Model for Visualization Design and Validation

Tamara Munzner
University of British Columbia
Department of Computer Science

How do you show your system is good?

- so many possible ways!
  - algorithm complexity analysis
  - field study with target user population
  - implementation performance (speed, memory)
  - informal usability study
  - laboratory user study
  - qualitative discussion of result pictures
  - quantitative metrics
  - requirements justification from task analysis
  - user anecdotes (insights found)
  - user community size (adoption)
  - visual encoding justification from theoretical principles

Contribution

- nested model unifying design and validation
  - guidance on when to use what validation method
  - different threats to validity at each level of model
- recommendations based on model

Four kinds of threats to validity

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- wrong **problem**
  - they don't do that

domain problem characterization

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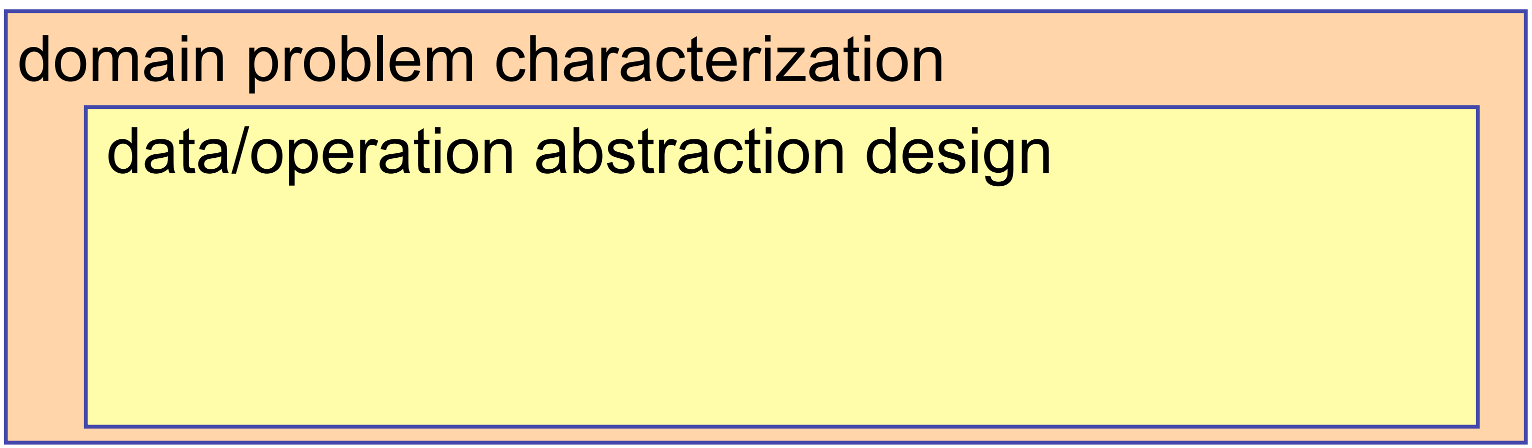
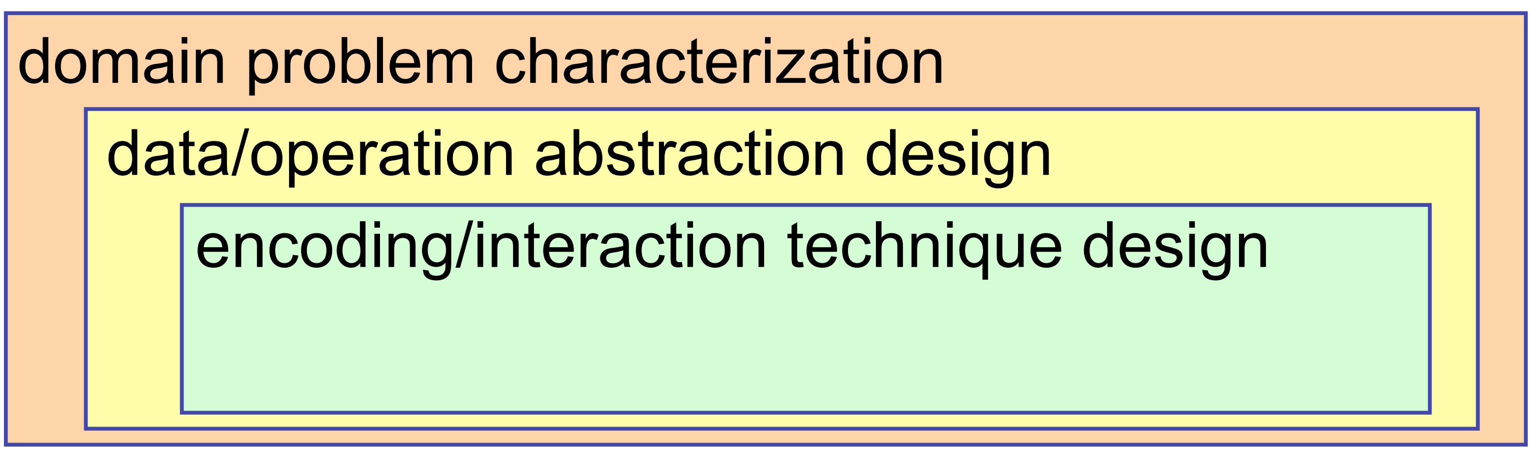
- wrong problem
  - they don’t do that
- wrong **abstraction**
  - you’re showing them the wrong thing



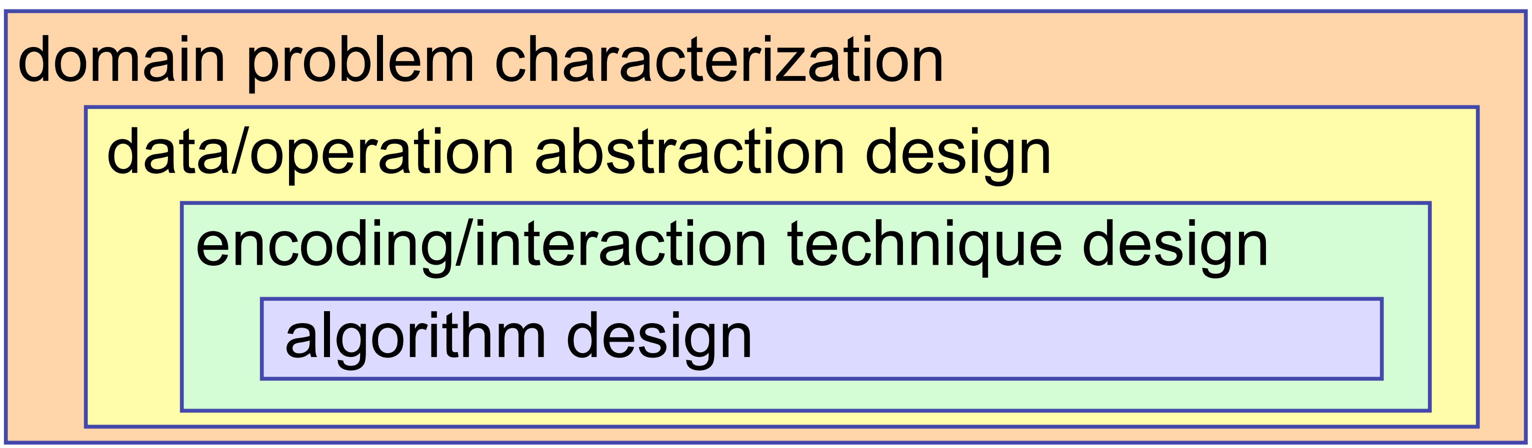
Four kinds of threats to validity

- wrong problem
  - they don’t do that
- wrong abstraction
  - you’re showing them the wrong thing
- wrong encoding/interaction **technique**
  - the way you show it doesn’t work



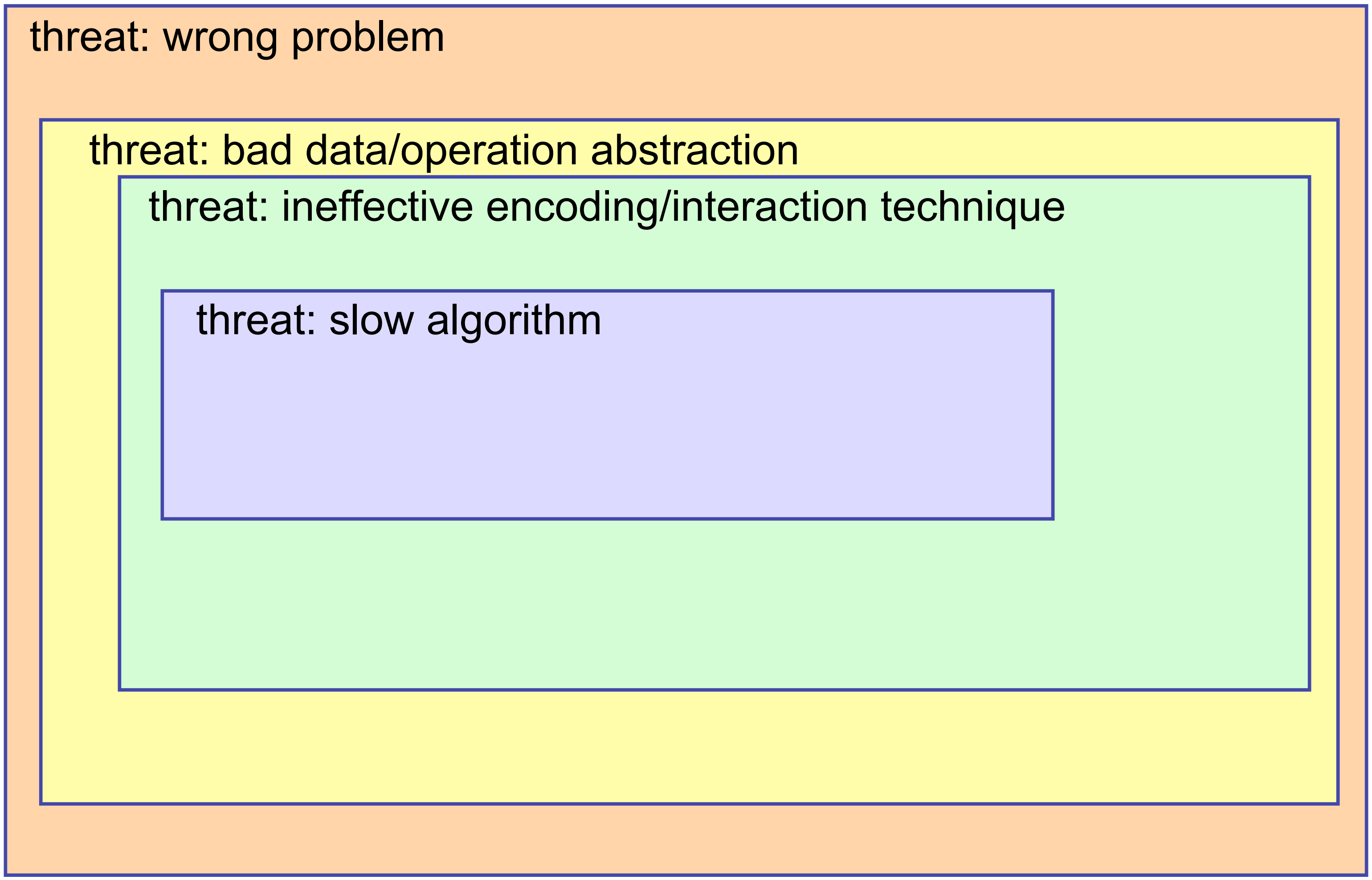
Four kinds of threats to validity

- wrong problem
  - they don't do that
- wrong abstraction
  - you're showing them the wrong thing
- wrong encoding/interaction technique
  - the way you show it doesn't work
- wrong **algorithm**
  - your code is too slow



Match validation method to contributions

- each validation works for only one kind of threat to validity



Analysis examples

MatrixExplorer. Henry and Fekete. InfoVis 2006.

- observe and interview target users
- justify encoding/interaction design
- measure system time/memory
- qualitative result image analysis

LiveRAC. McLachlan, Munzner, Koutsofios, and North. CHI 2008.

- observe and interview target users
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An energy model for visual graph clustering. (LinLog) Noack. Graph Drawing 2003

- qualitative/quantitative image analysis

Effectiveness of animation in trend visualization. Robertson et al. InfoVis 2008.

- lab study, measure time/errors for operation

Interactive visualization of genealogical graphs. McGuffin and Balakrishnan. InfoVis 2005.

- justify encoding/interaction design
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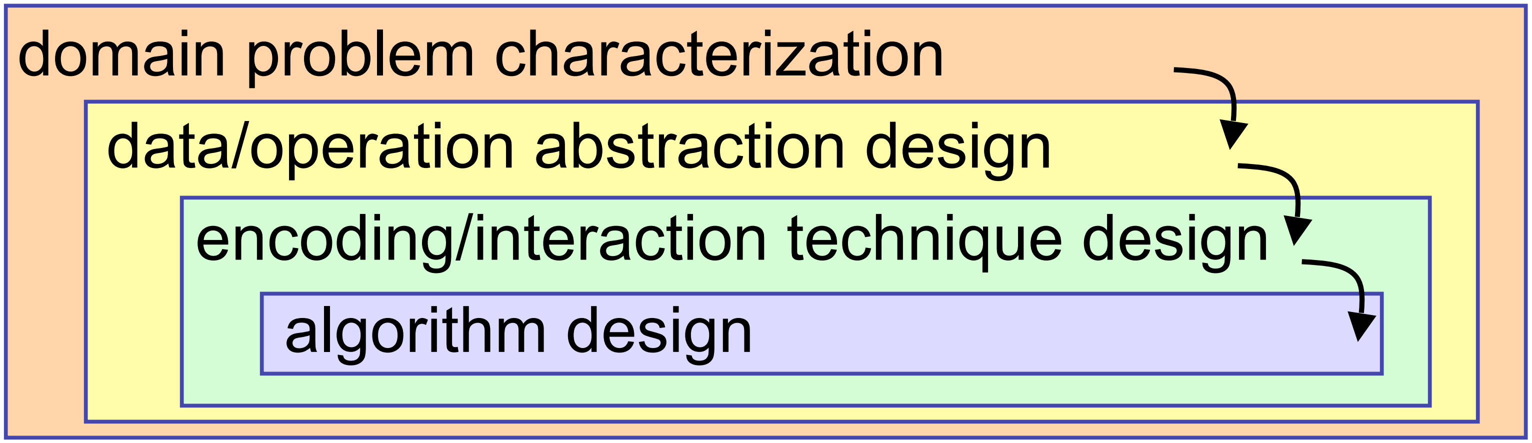
Flow map layout. Phan et al. InfoVis 2005.

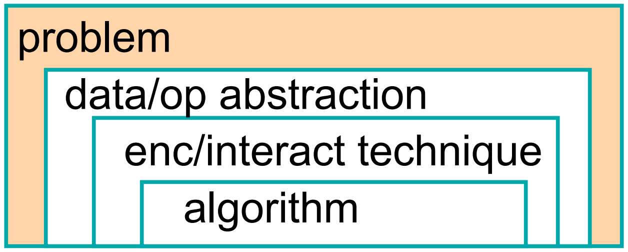
- justify encoding/interaction design
- computational complexity analysis
- measure system time/memory
- qualitative result image analysis

Nested levels in model

- output of **upstream** level → input to **downstream** level
- challenge: upstream errors inevitably cascade
  - if poor abstraction choice made, even perfect technique and algorithm design will not solve intended problem

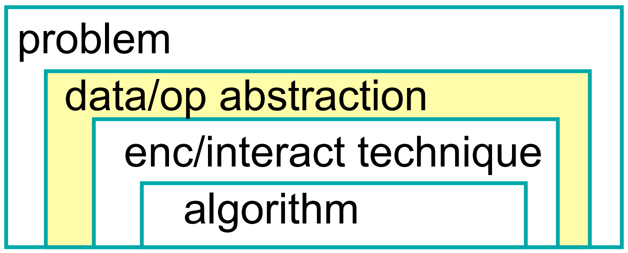


Characterizing domain problems



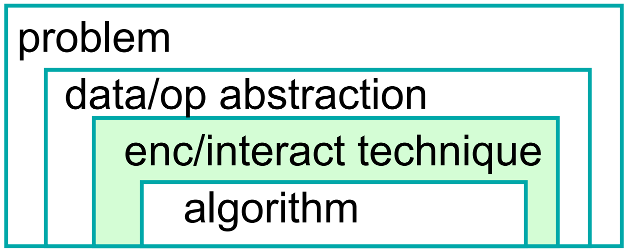
- tasks, data, workflow of target users
  - **problems**: tasks described in domain terms
  - requirements elicitation is notoriously hard

Designing data/operation abstraction

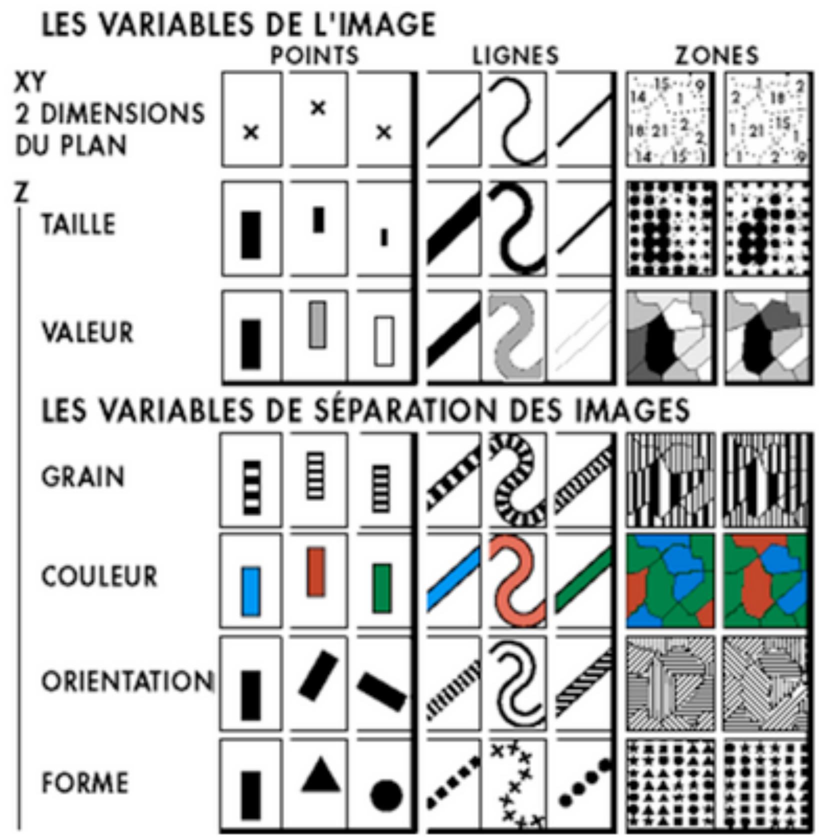


- mapping from domain vocabulary/concerns to abstraction
  - may require transformation!
- **data types**: data described in abstract terms
  - numeric tables, relational/network, spatial, ...
- **operations**: tasks described in abstract terms
  - generic
    - sorting, filtering, correlating, finding trends/outliers...
  - datatype-specific
    - path following through network...

Designing encoding,interaction techniques

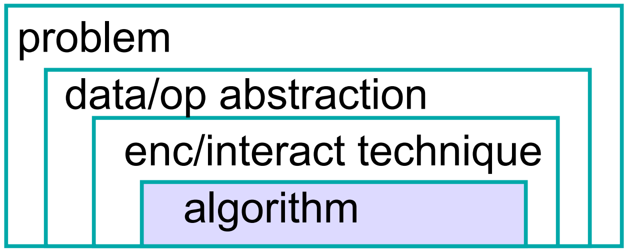


- visual encoding
  - marks, attributes, ...
  - extensive foundational work exists
- interaction
  - selecting, navigating, ordering, ...
  - significant guidance exists



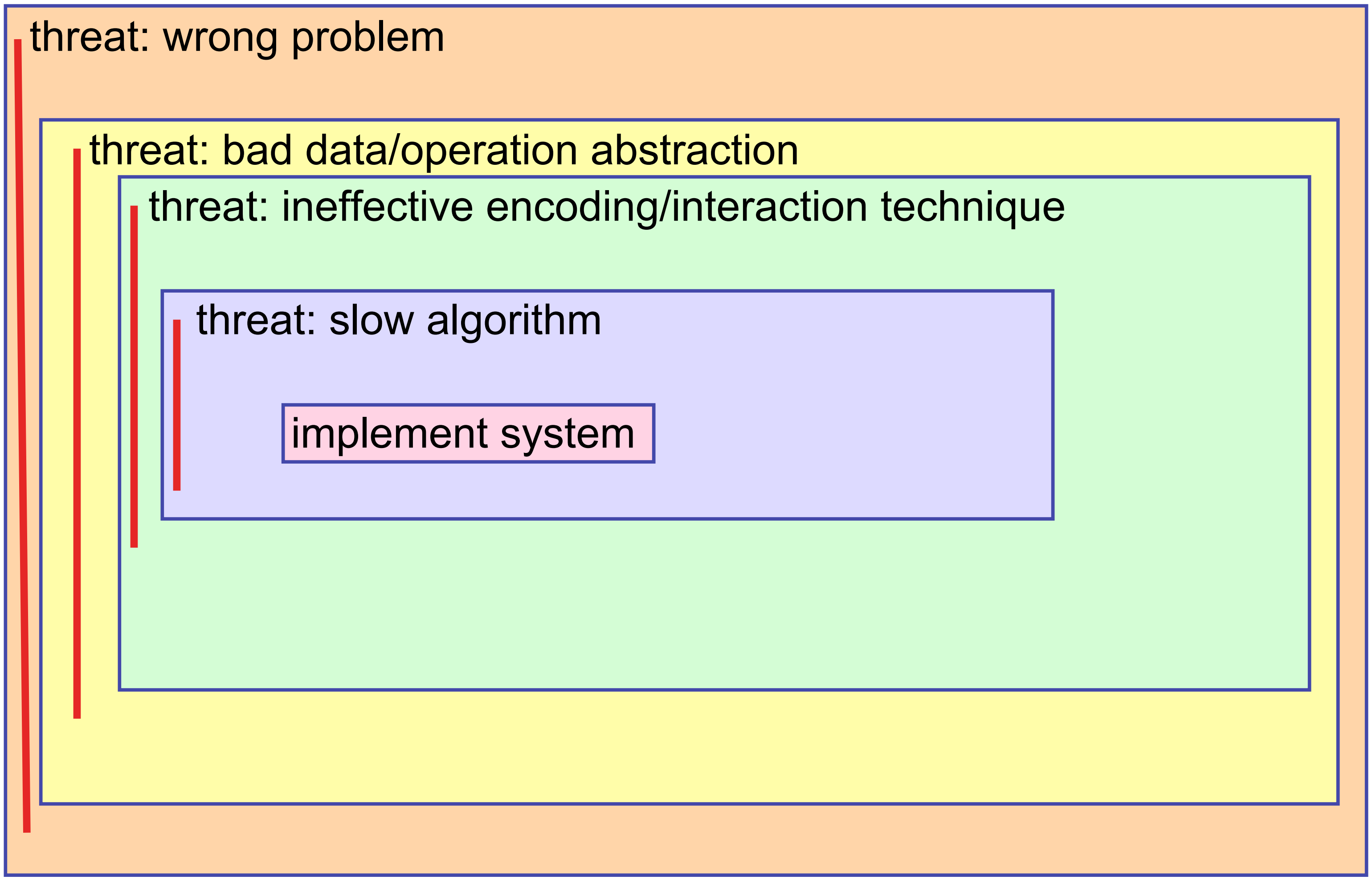
Semiology of Graphics. Jacques Bertin, Gauthier-Villars 1967, EHESS 1998

Designing algorithms



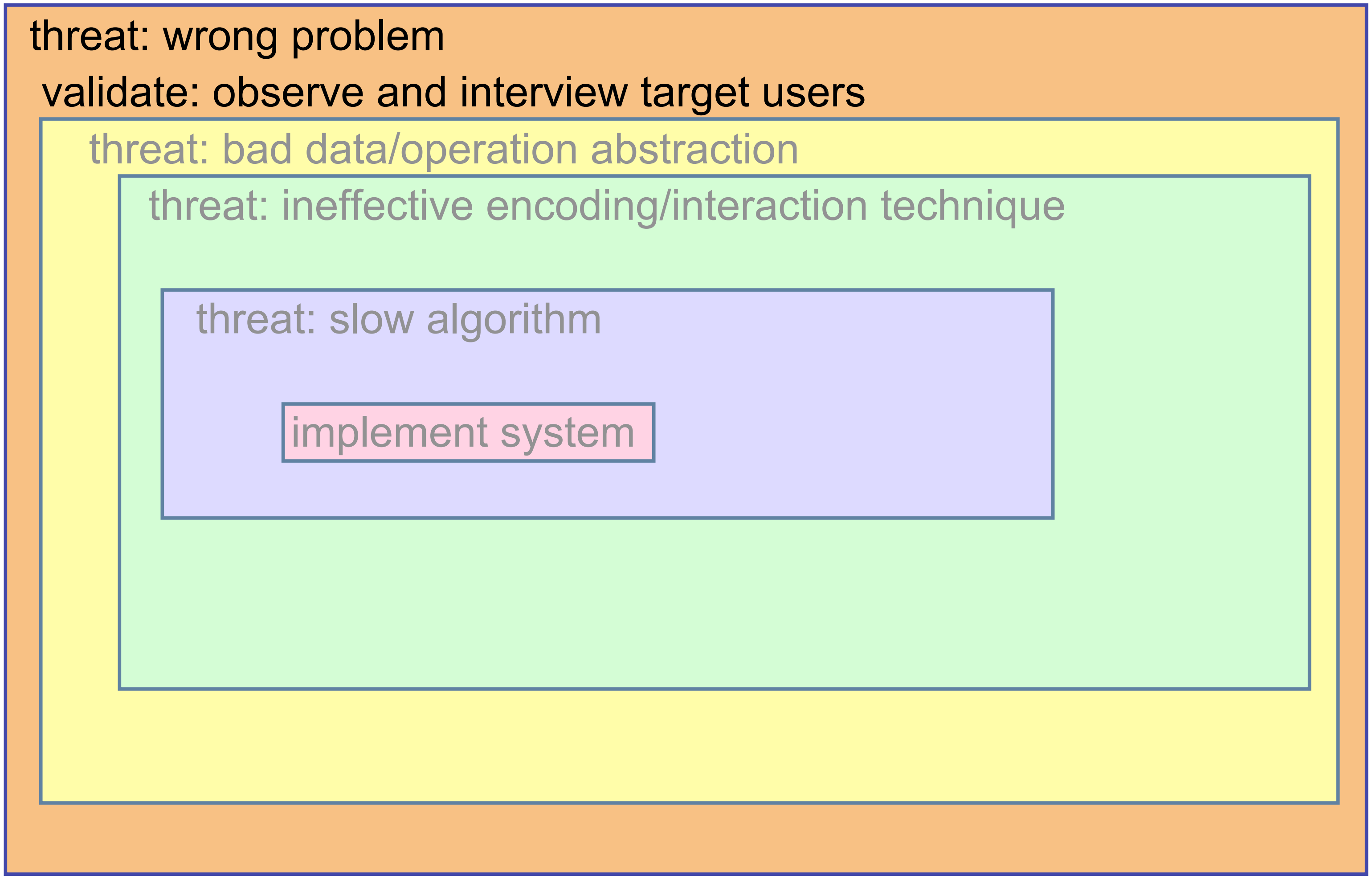
- well-studied computer science problem
  - create efficient algorithm given clear specification
  - no human-in-loop questions

Immediate vs. downstream validation



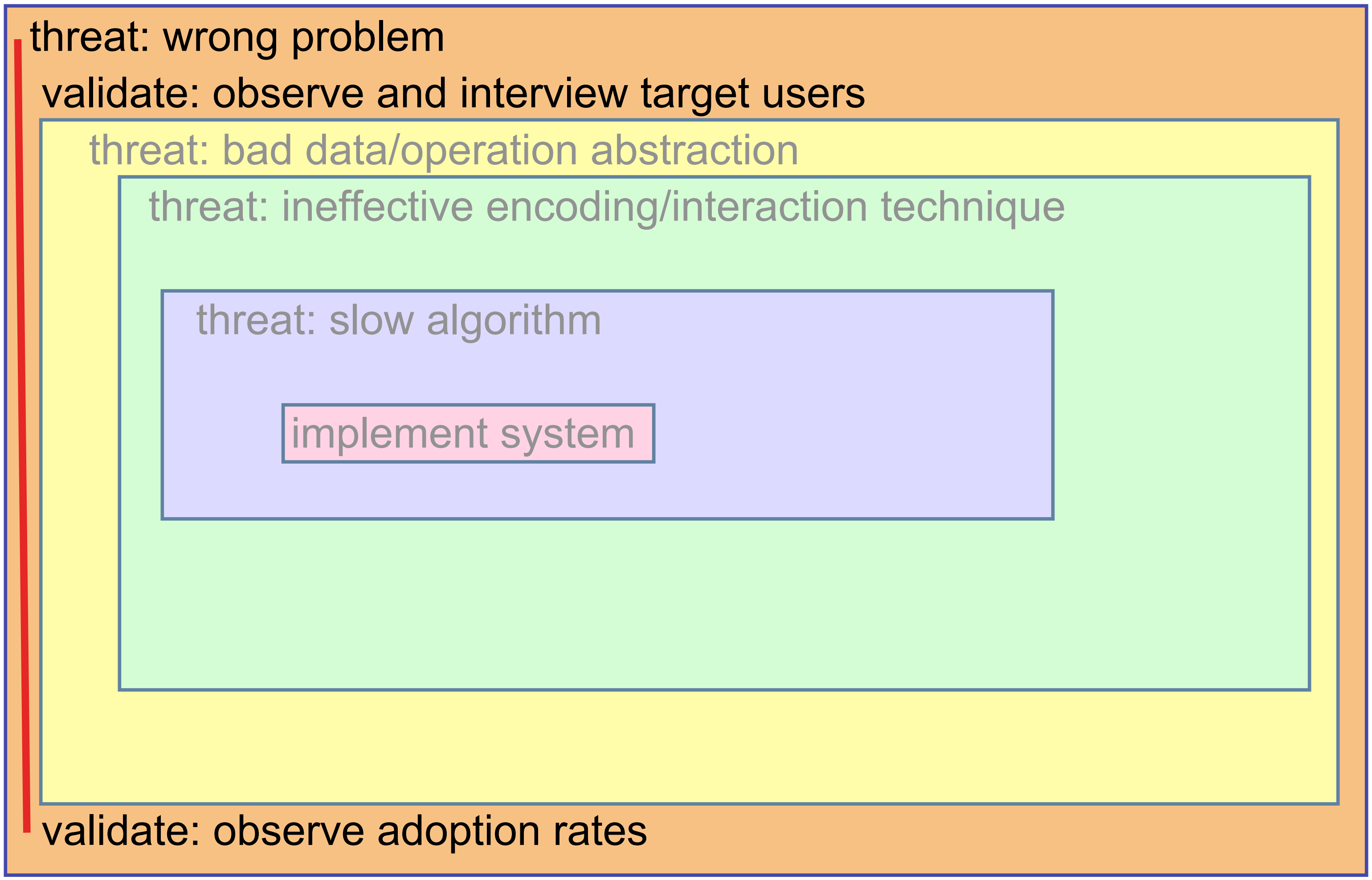
Domain problem validation

- immediate: ethnographic interviews/observations



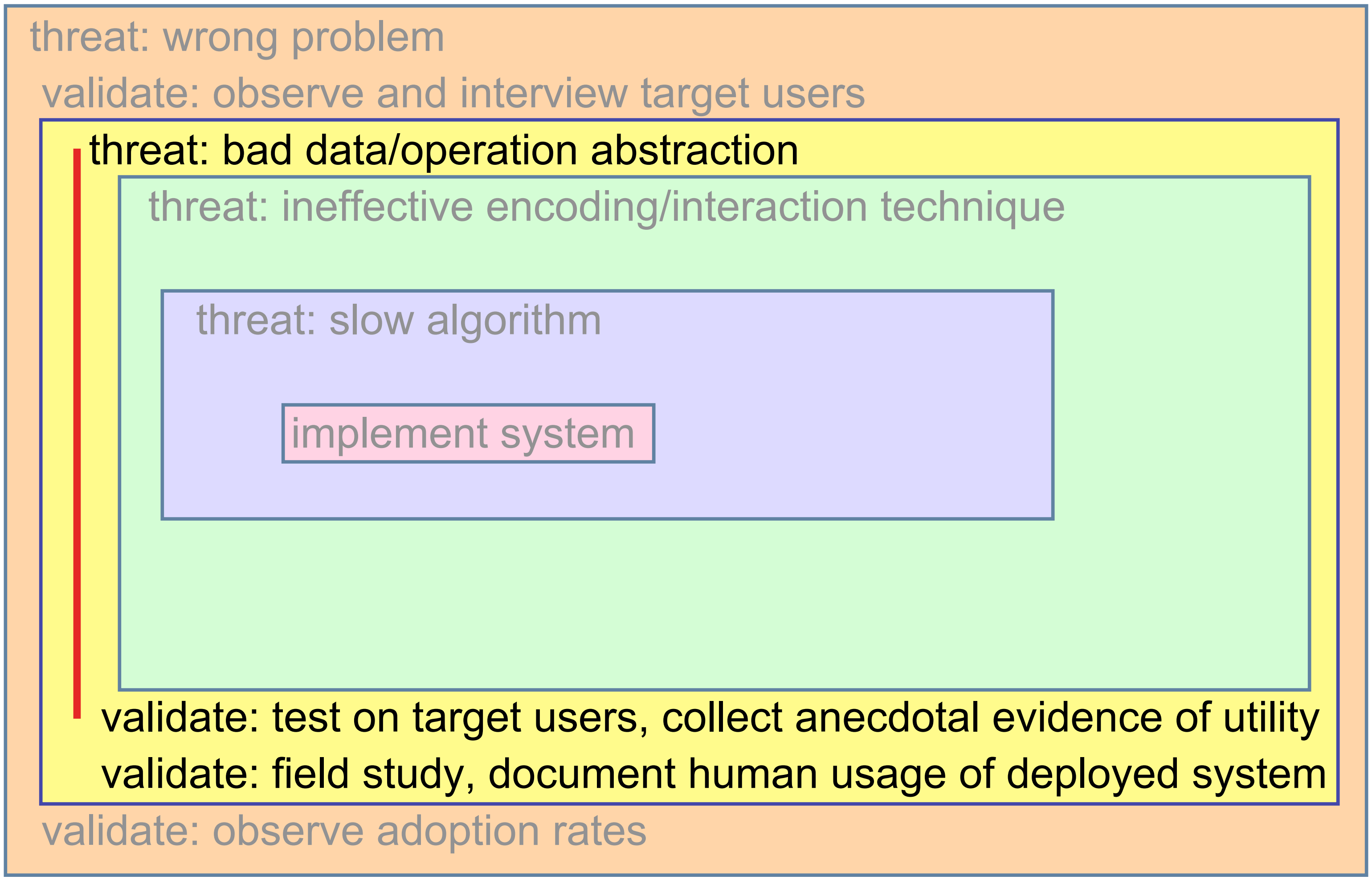
Domain problem validation

- downstream: adoption (weak but interesting signal)



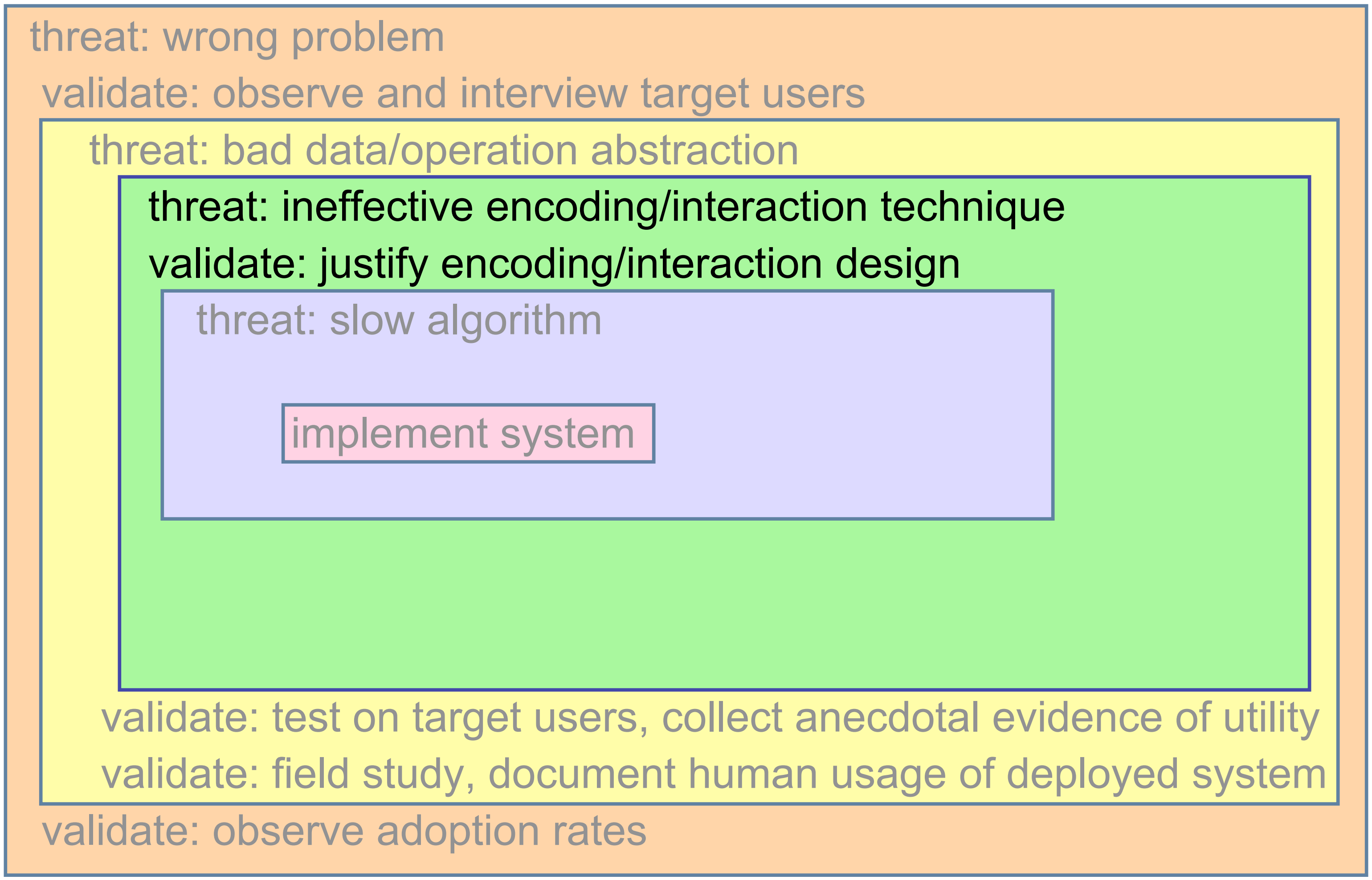
Abstraction validation

- downstream: can only test with target users doing real work



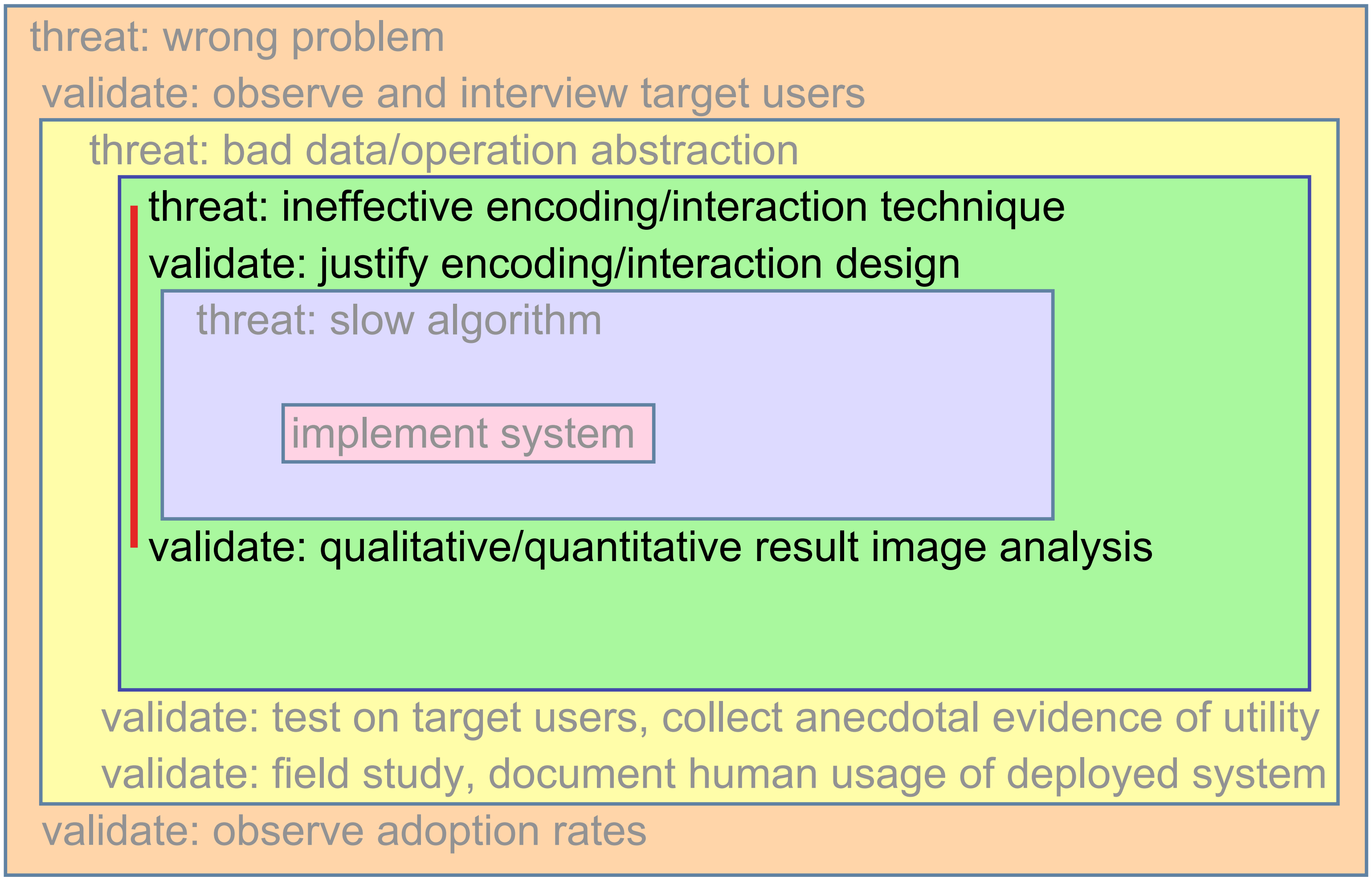
Encoding/interaction technique validation

- immediate: justification useful, but not sufficient - tradeoffs



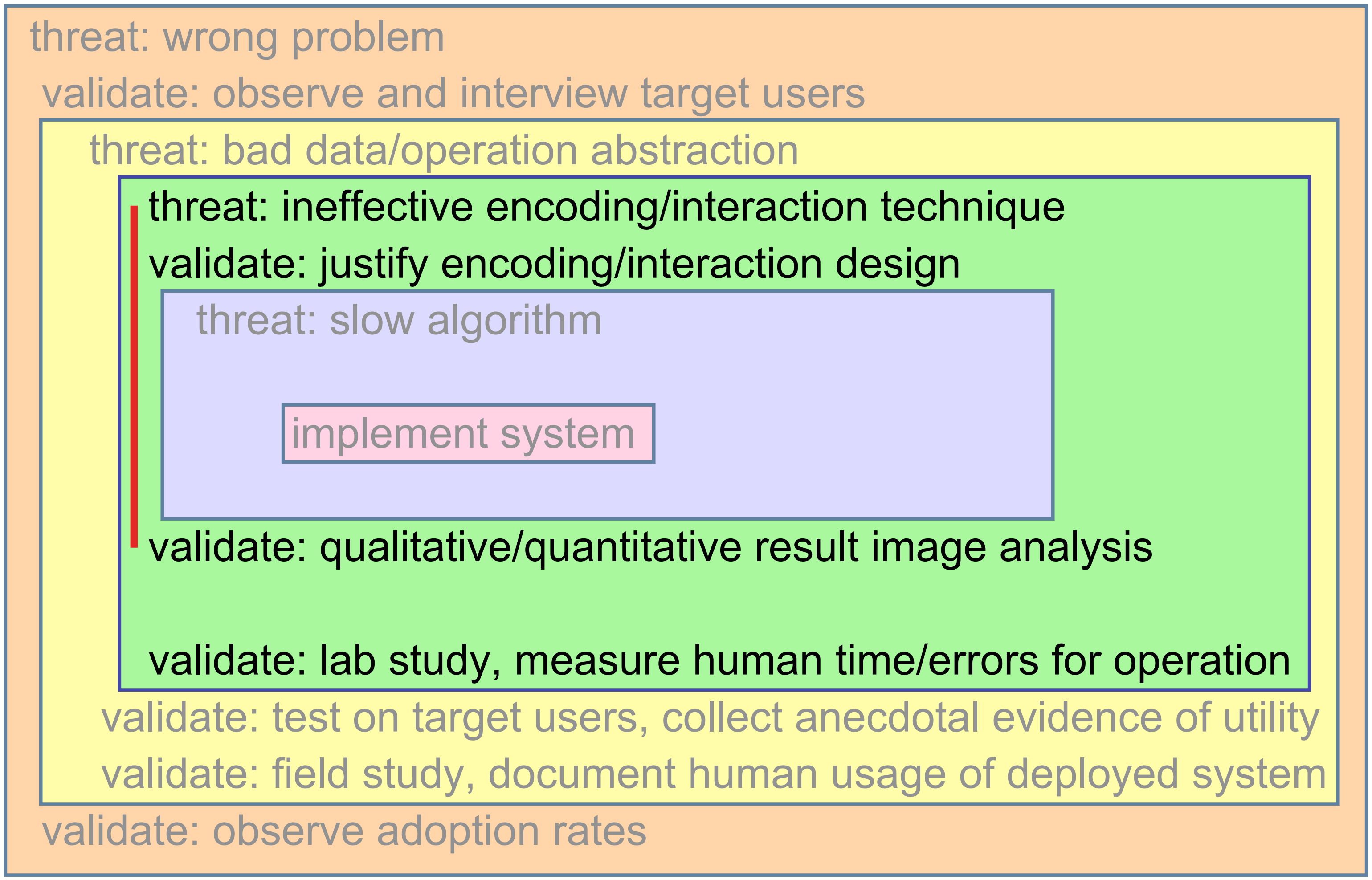
Encoding/interaction technique validation

- downstream: discussion of result images very common



Encoding/interaction technique validation

- downstream: studies add another level of rigor (and time)



Encoding/interaction technique validation

- usability testing necessary for validity of downstream testing
  - not validation method itself!

threat: wrong problem

validate: observe and interview target users

threat: bad data/operation abstraction

threat: ineffective encoding/interaction technique

validate: justify encoding/interaction design

threat: slow algorithm

implement system

validate: qualitative/quantitative result image analysis

[test on any users, informal usability study]

validate: lab study, measure human time/errors for operation

validate: test on target users, collect anecdotal evidence of utility

validate: field study, document human usage of deployed system

validate: observe adoption rates

Algorithm validation

- immediate vs. downstream here clearly understood in CS

threat: wrong problem
validate: observe and interview target users
threat: bad data/operation abstraction
threat: ineffective encoding/interaction technique
validate: justify encoding/interaction design
threat: slow algorithm
validate: analyze computational complexity
implement system
validate: measure system time/memory
validate: qualitative/quantitative result image analysis
[test on any users, informal usability study]
validate: lab study, measure human time/errors for operation
validate: test on target users, collect anecdotal evidence of utility
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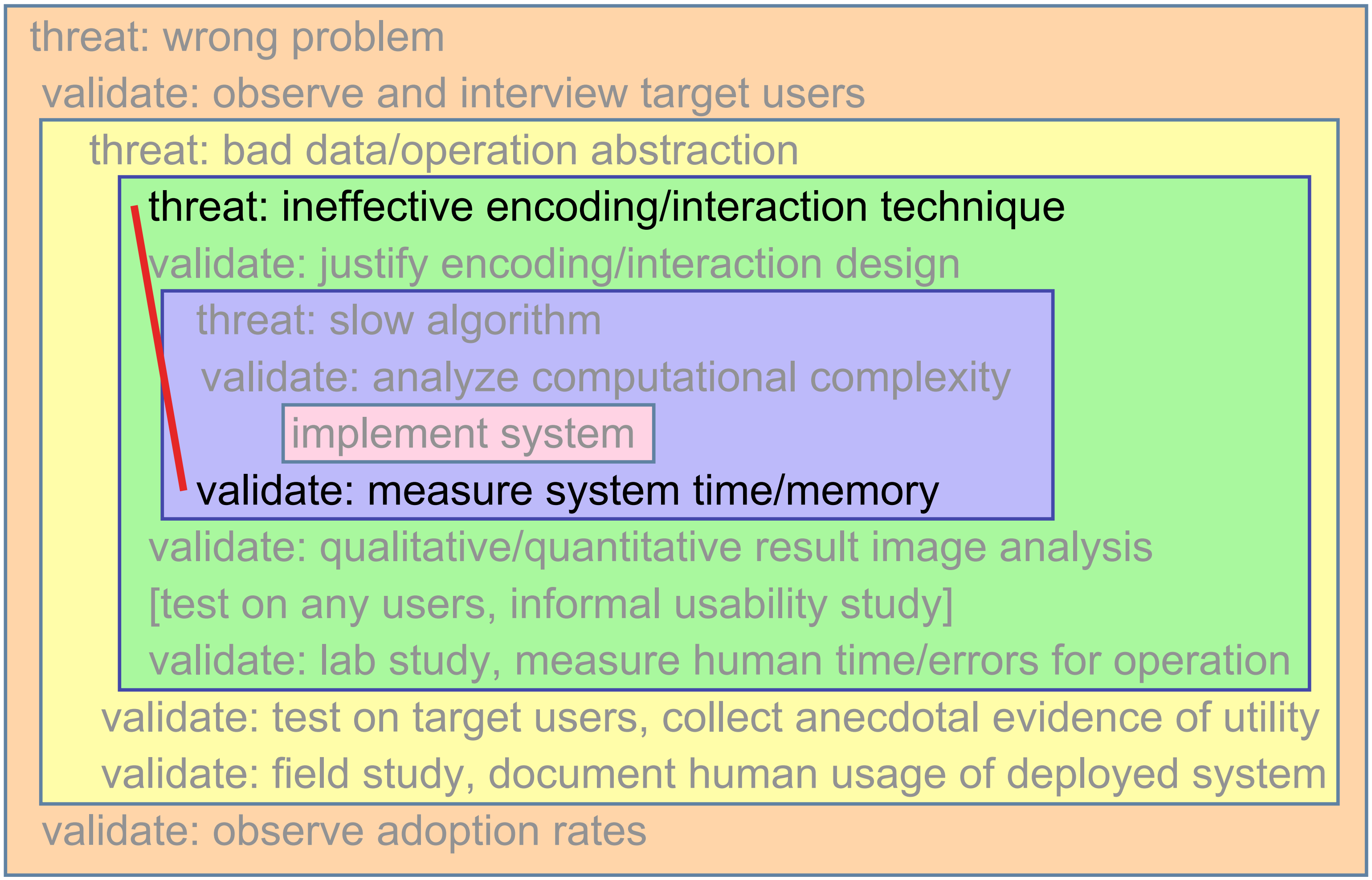
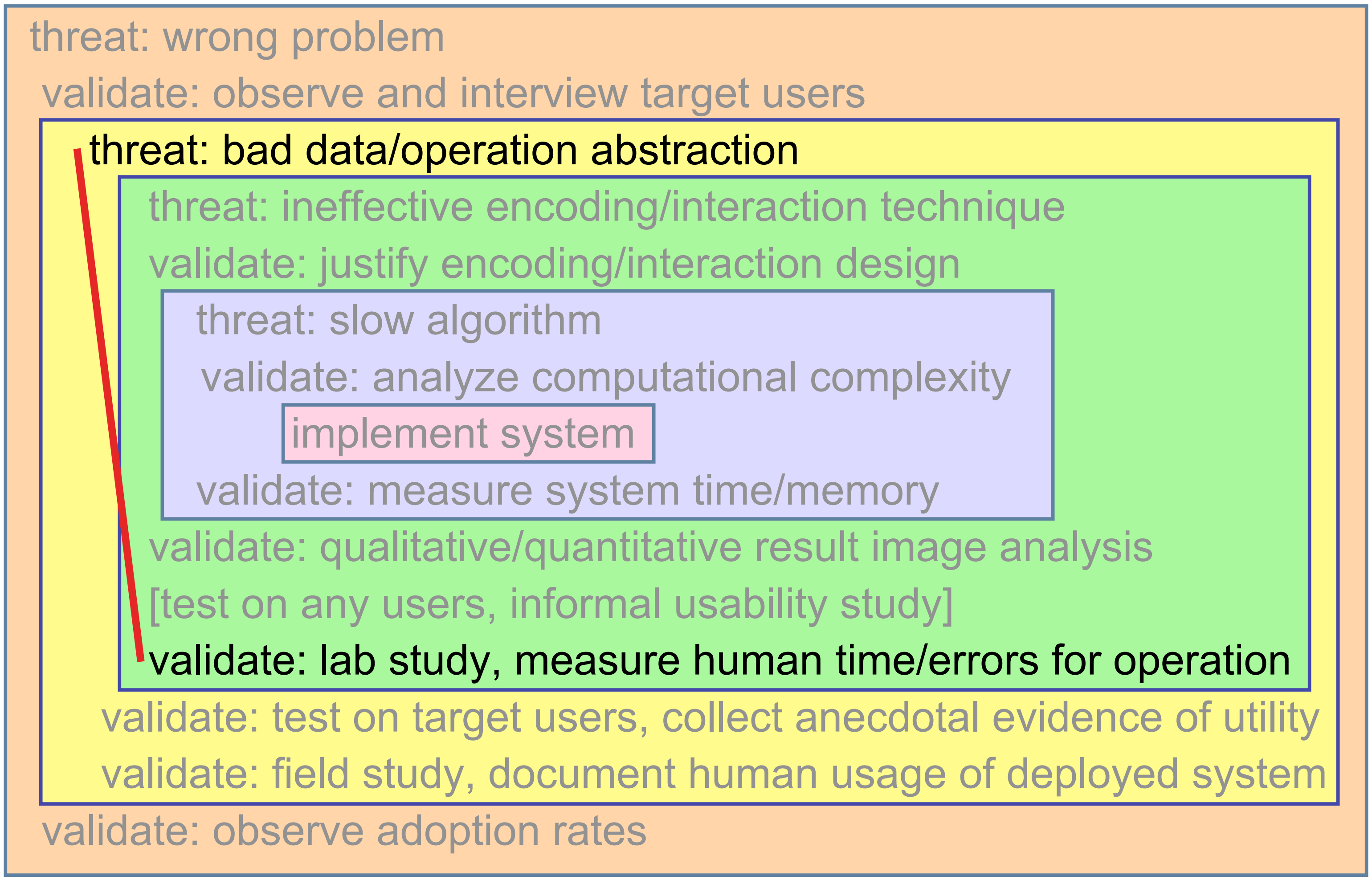
Avoid mismatches

- can't validate encoding with wallclock timings



Avoid mismatches

- can’t validate abstraction with lab study



Single paper would include only subset

- can't do all for same project
  - not enough space in paper or time to do work

threat: wrong problem
validate: observe and interview target users
threat: bad data/operation abstraction
threat: ineffective encoding/interaction technique
validate: justify encoding/interaction design
threat: slow algorithm
validate: analyze computational complexity
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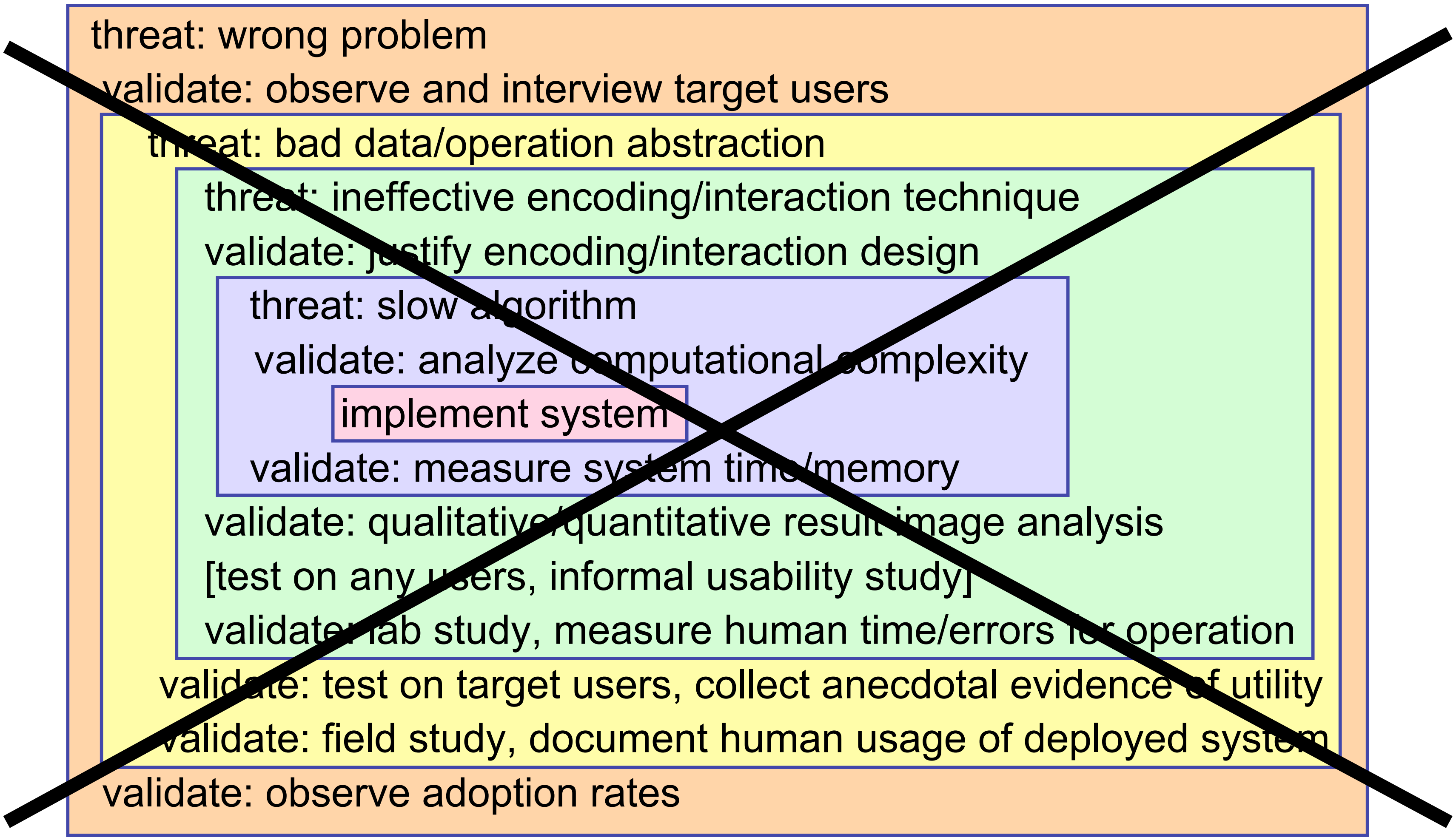
Single paper would include only subset

- pick validation method according to contribution claims



Real design process

- iterative refinement
  - levels don't need to be done in strict order
  - intellectual value of level separation
    - exposition, analysis
- shortcut across inner levels + implementation
  - rapid prototyping, etc.
    - low-fidelity stand-ins so downstream validation can happen sooner

Related work

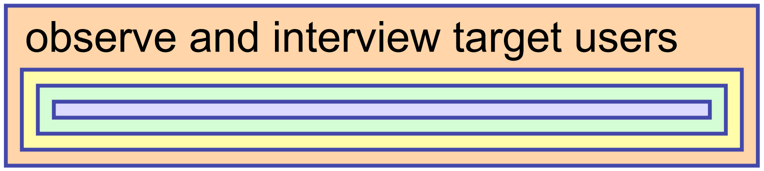
- influenced by many previous pipelines
  - but none were tied to validation
    - [Card, Mackinlay, Shneiderman 99], ...
- many previous papers on how to evaluate
  - but not when to use what validation methods
    - [Carpendale 08], [Plaisant 04], [Tory and Möller 04]
  - exceptions
    - good first step, but no formal framework
      [Kosara, Healey, Interrante, Laidlaw, Ware 03]
    - guidance for long term case studies, but not other contexts
      [Shneiderman and Plaisant 06]
    - only three levels, does not include algorithm
      [Ellis and Dix 06], [Andrews 08]

Recommendations: authors

- explicitly state level of contribution claim(s)
- explicitly state assumptions for levels upstream of paper focus
  - just one sentence + citation may suffice
- goal: literature with clearer interlock between papers
  - better unify problem-driven and technique-driven work

Recommendation: publication venues

- we need more problem characterization
  - ethnography, requirements analysis
- as part of paper, and as full paper
  - now full papers relegated to CHI/CSCW
    - does not allow focus on central vis concerns
  - **legitimize ethnographic "orange-box" papers!**



Lab study as core now deemed legitimate

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Limitations

- oversimplification
- not all forms of user studies addressed
- infovis-oriented worldview
- are these levels the right division?

Conclusion

- new model unifying design and validation
  - guidance on when to use what validation method
  - broad scope of validation, including algorithms
- recommendations
  - be explicit about levels addressed and state upstream assumptions so papers interlock more
  - we need more problem characterization work

these slides posted at http://www.cs.ubc.ca/~tmm/talks.html#iv09