Object-Oriented Software Engineering
Conquering Complex and Changing Systems

Rationale Management

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An aircraft example

A320

- ♦ First fly-by-wire passenger aircraft
- ♦ 150 seats, short to medium haul

A319 & A321

- ♦ Derivatives of A320
- ♦ Same handling as A320

Design rationale

- ♦ Reduce pilot training & maintenance costs
- ♦ Increase flexibility for airline

A319
A319
A320
A320
A321
A321

An aircraft example (2)

A330 & A340

- ♦ Long haul and ultra long haul
- ♦ 2x seats, 3x range
- ♦ Similar handling than A320 family

Design rationale

- ♦ With minimum cross training, A320 pilots can be certified to fly A330 and A340 airplanes

Consequence

- ♦ Any change in these five airplanes must maintain this similarity

Overview: rationale

- What is rationale?
- Why is it critical in software engineering?
- Centralized traffic control example
- Representing rationale
- Capturing rationale
- Maintaining rationale
- Open issues

- Questions?

What is rationale?

Rationale is the reasoning that lead to the system.

Rationale includes:

- ♦ the ***issues*** that were addressed,
- ♦ the ***alternatives*** that were considered,
- ♦ the ***decisions*** that were made to resolve the issues,
- ♦ the ***criteria*** that were used to guide decisions, and
- ♦ the ***debate*** developers went through to reach a decision.

Why is rationale important in software engineering?

Many software systems are like aircraft:

They result from a large number of decisions taken over an extended period of time.

- ♦ Evolving assumptions
- ♦ Legacy decisions
- ♦ Conflicting criteria

-> high maintenance cost

-> loss & rediscovery of information

Uses of rationale in software engineering

- Improve design support
  - **Avoid duplicate evaluation of poor alternatives**
  - **Make consistent and explicit trade-offs**
- Improve documentation support
  - **Makes it easier for non developers (e.g., managers, lawyers, technical writers) to review the design**
- Improve maintenance support
  - **Provide maintainers with design context**
- Improve learning
  - **New staff can learn the design by replaying the decisions that produced it**

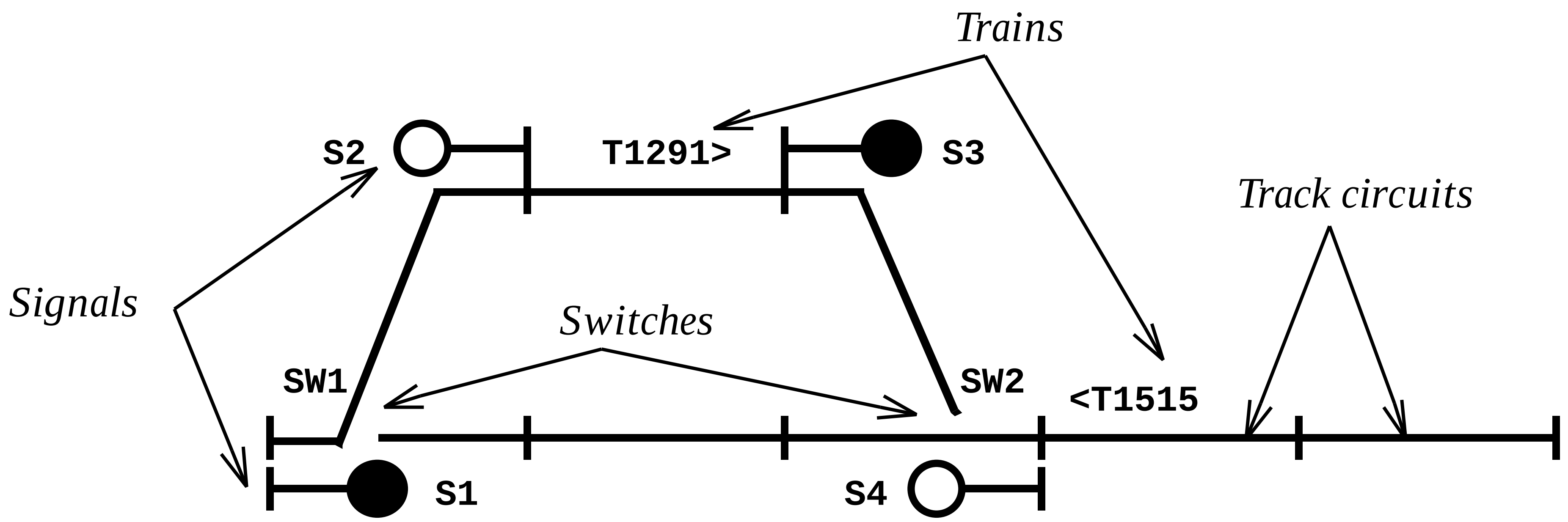
Example: sort algorithm

Requirements:	***what** should the system do?*
Design:	***how** should it do it?*
Rationale:	***why** does it dot it the way it does?*

Rationale includes:

Decisions	**`Let’s use insert_sort`**
Justifications	**`The data are quasi sorted`**
Alternatives	**`quick_sort`**
	`bubble_sort`
Tradeoffs	**`worst vs. common case`**
	`speed vs. space`
Argumentation	**`Quick_sort performs badly on quasi sorted data`**

Centralized traffic control



- CTC systems enable dispatchers to monitor and control trains remotely
- CTC allows the planning of routes and replanning in case of problems

Centralized traffic control (2)

CTC systems are ideal examples of rationale capture:

- Long lived systems (some systems include relays installed last century)
  - **Extended maintenance life cycle**
- Although not life critical, downtime is expensive
  - **Low tolerance for bugs**
  - **Transition to mature technology**

Representing rationale

Many media and forms are available for representing rationale information:

- ♦ Video & audio
- ♦ Transcripts
- ♦ Online communication traffic
- ♦ Paper

- ♦ Communication records
- ♦ Design documentation
- ♦ Argumentation

Representing rationale: issue models

Argumentation is the most promising approach so far:

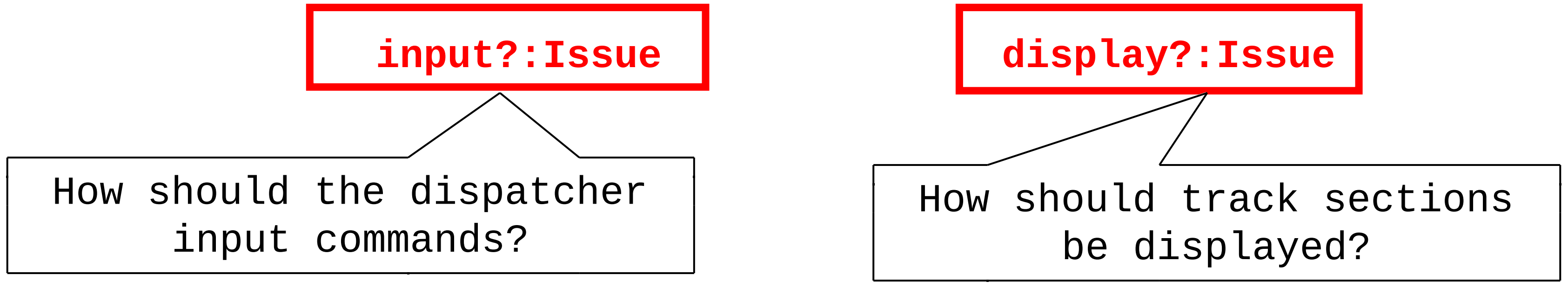
- More information than document: captures trade-offs and discarded alternatives that design documents do not.
- Less messy than communication records: communication records contain everything.

Issue models represent arguments in a semi-structure form:

- Nodes represent argument steps
- Links represent their relationships

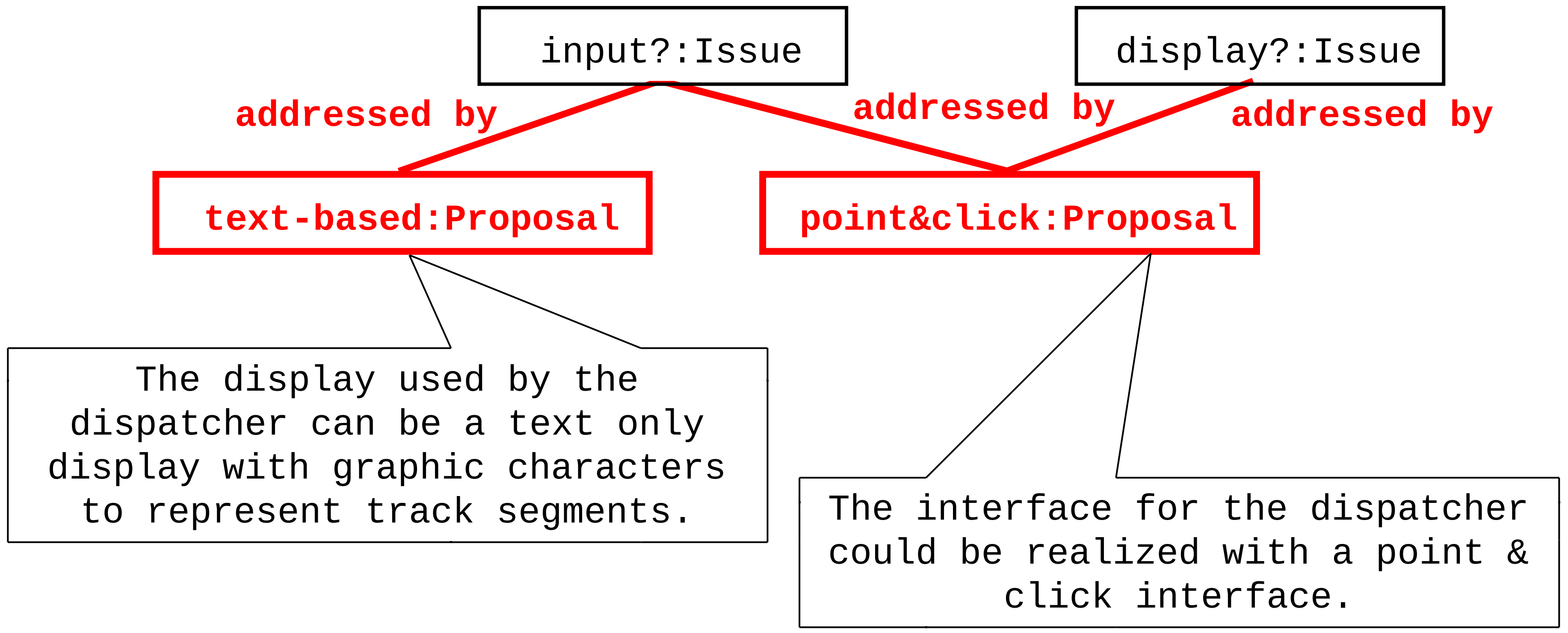
Issues

- Issues are concrete problem which usually do not have a unique, correct solution.
- Issues are phrased as questions.


input?:Issue
display?:Issue
How should the dispatcher input commands?
How should track sections be displayed?

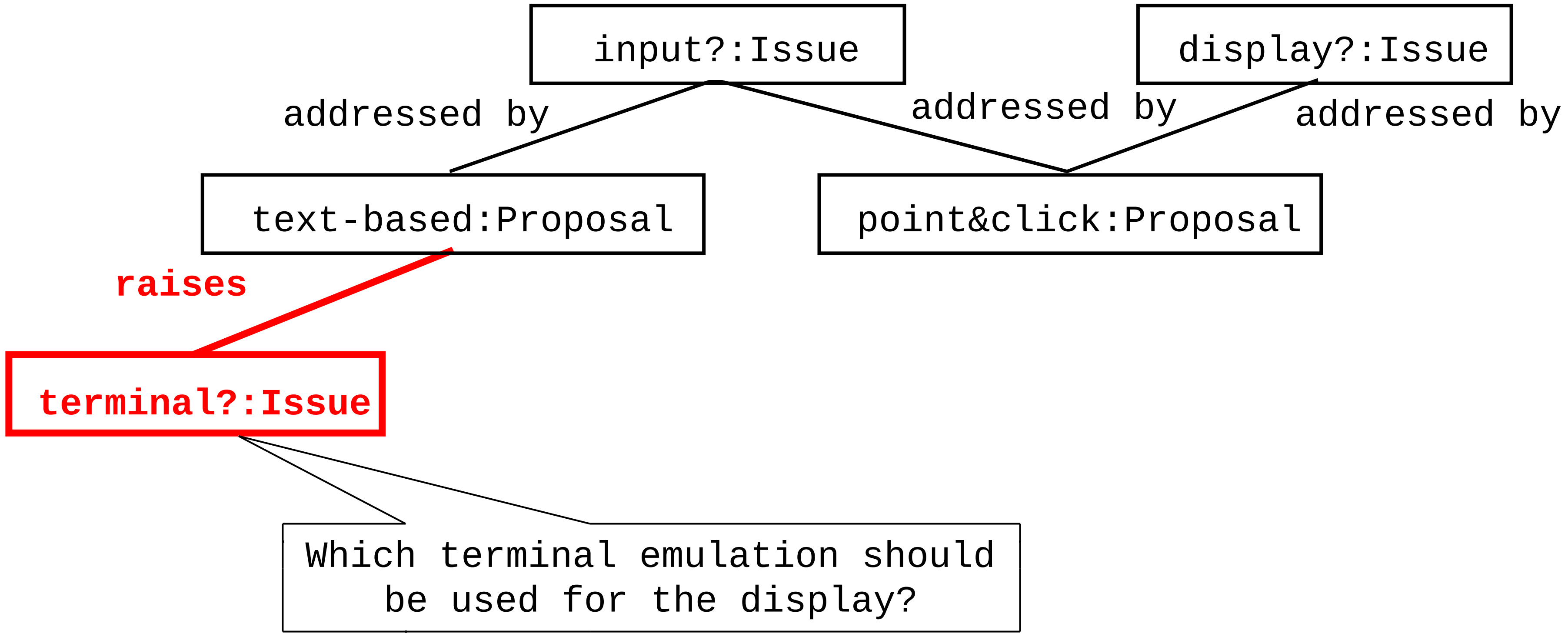
Proposals

- Proposals are possible alternatives to issues.
- One proposal can be shared across multiple issues.


input?:Issue
display?:Issue
addressed by
addressed by
addressed by
text-based:Proposal
point&click:Proposal
The display used by the dispatcher can be a text only display with graphic characters to represent track segments.
The interface for the dispatcher could be realized with a point & click interface.

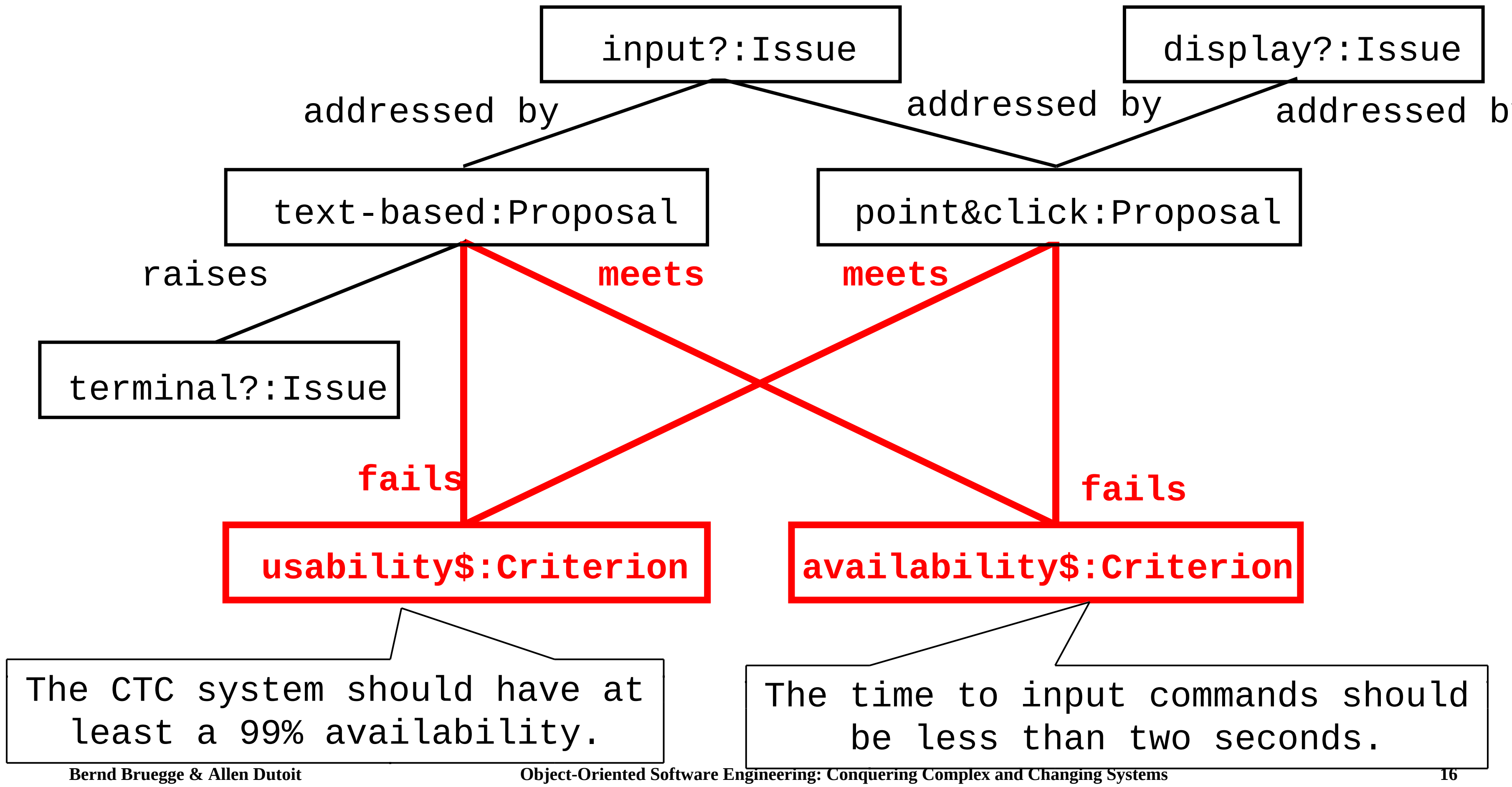
Consequent issue

♦ Consequent issues are issues raised by the introduction of a proposal.



Criteria

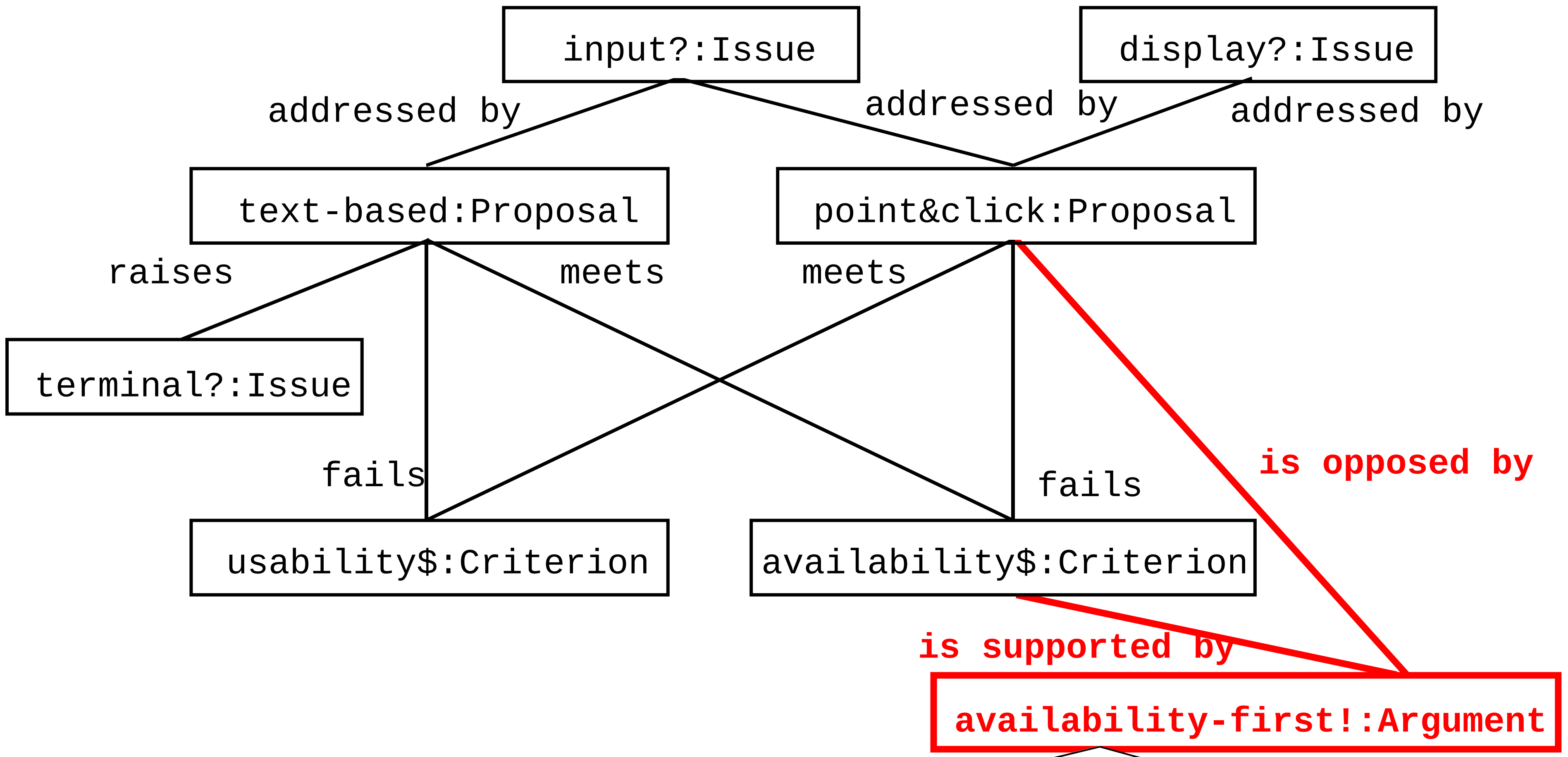
- A criteria represent a goodness measure.
- Criteria are often design goals or nonfunctional requirements.



Arguments

- Arguments represent the debate developers went through to arrive to resolve the issue.
- Arguments can support or oppose any other part of the rationale.
- Arguments constitute the most part of rationale.

Arguments (2)

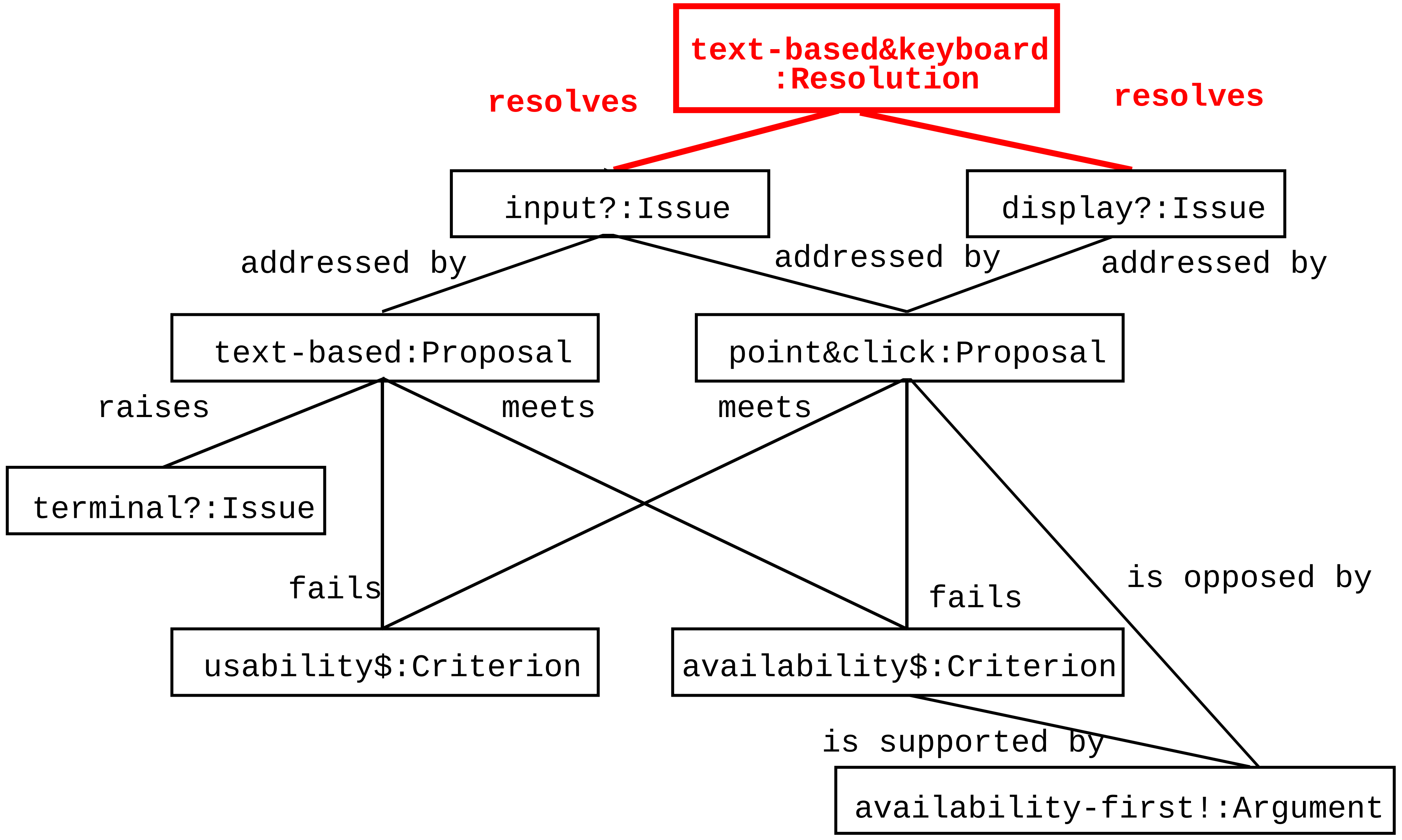


Point&click interfaces are more complex to implement than text-based interfaces. Hence, they are also more difficult to test. The point&click interface risks introducing fatal errors in the system that would offset any usability benefit the interface would provide.

Resolutions

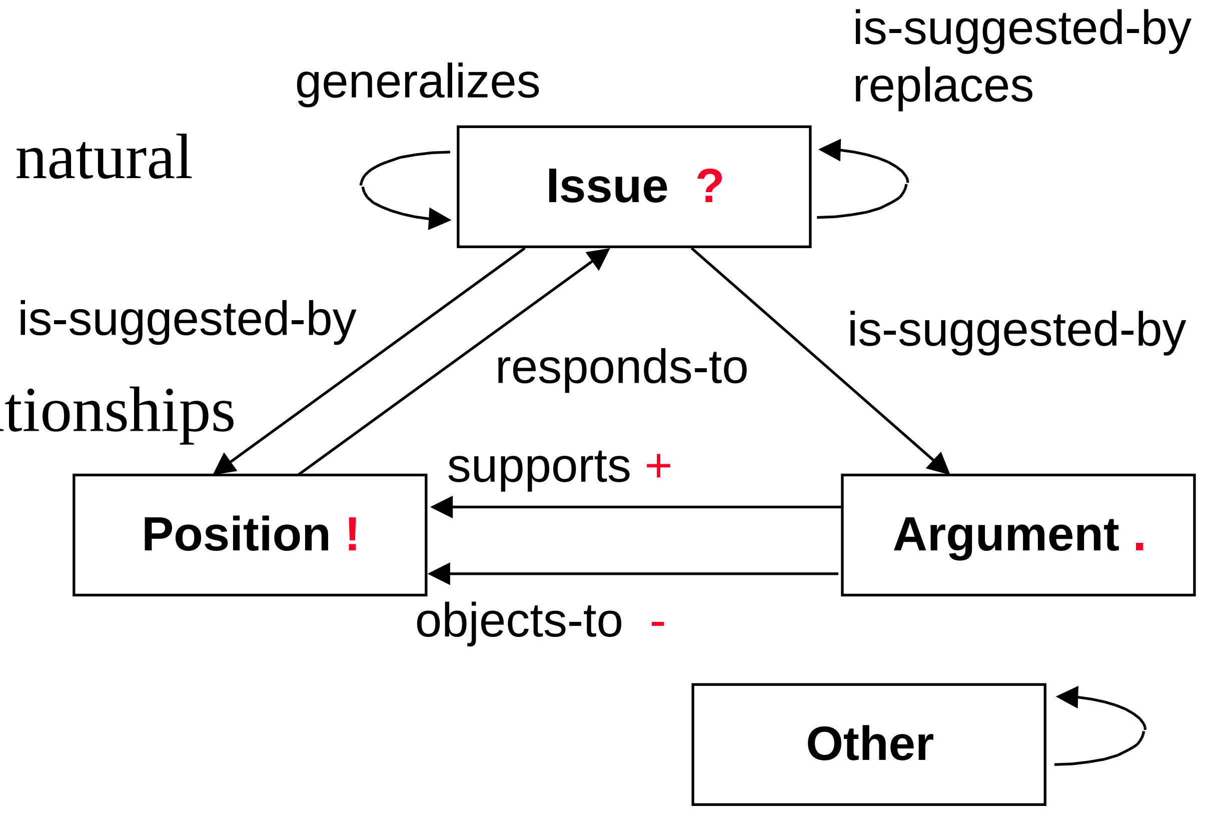
- Resolutions represent decisions.
- A resolution summarizes the chosen alternative and the argument supporting it.
- A resolved issue is said to be closed.
- A resolved issue can be re-opened if necessary, in which case the resolution is demoted.

Resolutions (2)



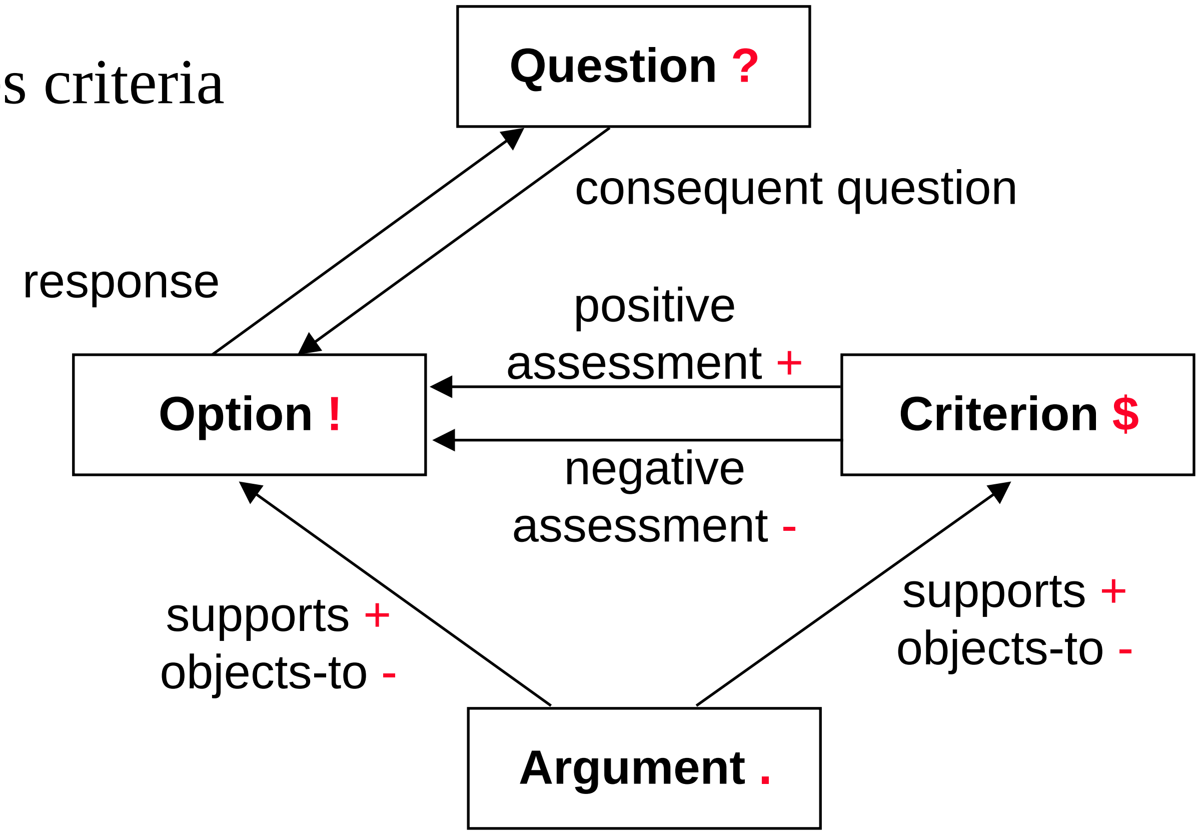
Other issue models: Issue-Based Information System

- Semi structured notation for capturing rationale as decisions are made.
- Nodes are pieces of natural language text
- Links represent relationships between nodes

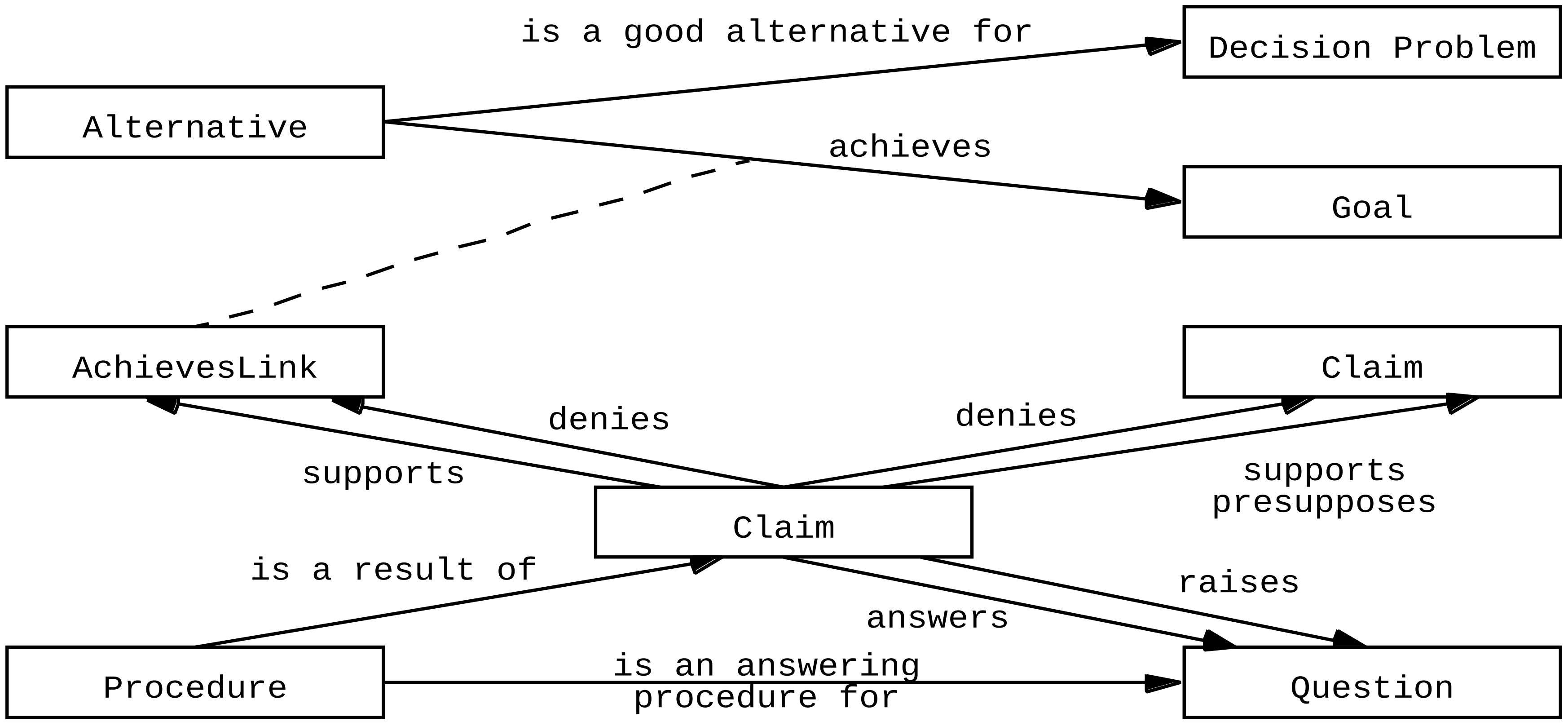


Other issue models: Questions, Options, Criteria

- Designed for capturing rationale after the fact (e.g., quality assessment).
- Similar to IBIS
- QOC emphasizes criteria



Other issue models: Decision Representation Language



Capturing rationale

Possible approaches to capturing rationale

- ♦ Reconstruction
- ♦ Record-and-replay
- ♦ Byproduct of development method

Requirements

- ♦ Non disruptive: it should not interfere with design
- ♦ Integrated with development

Capturing rationale: reconstruction

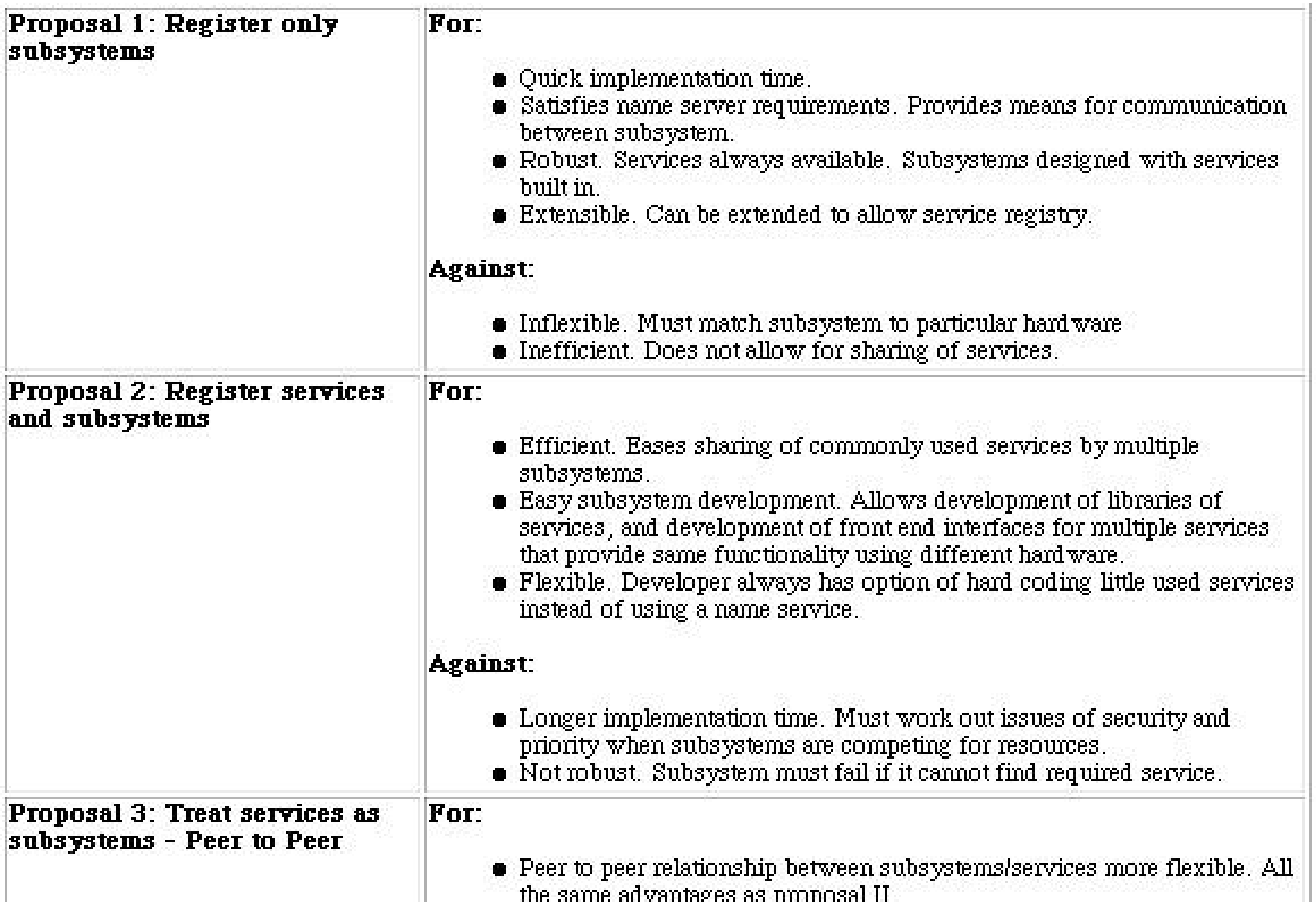
- A librarian is assigned to role to reconstruct the system's rationale
- Developers are interviewed and surveyed
- Reconstructing rationale is similar to technical documentation

- Advantages
  - **Captures justifications of selected alternatives**
  - **Relatively accurate when done shortly after development**
- Disadvantages
  - **Misses discarded alternatives**
  - **Difficult to maintain history of changes**

Rationale reconstruction: example

- JAMES’97
  - **Smartcard architecture for automotive industry**
  - **Demonstration prototype**
  - **~40 participants**
- System Design Document (SDD)
  - **Documents system level design decision and their rationale**
  - **Asked each participants to reconstruct the rationale for one issue**
- Result
  - **17 fully documented design issues**
  - **~20 pages, rationale is the largest section in the SDD**
  - **Positive feedback from the client**

JAMES SDD excerpt



Proposal 1: Register only subsystems	**For:** ● Quick implementation time. ● Satisfies name server requirements. Provides means for communication between subsystem. ● Robust. Services always available. Subsystems designed with services built in. ● Extensible. Can be extended to allow service registry. **Against:** ● Inflexible. Must match subsystem to particular hardware ● Inefficient. Does not allow for sharing of services.
Proposal 2: Register services and subsystems	**For:** ● Efficient. Eases sharing of commonly used services by multiple subsystems. ● Easy subsystem development. Allows development of libraries of services, and development of front end interfaces for multiple services that provide same functionality using different hardware. ● Flexible. Developer always has option of hard coding little used services instead of using a name service. **Against:** ● Longer implementation time. Must work out issues of security and priority when subsystems are competing for resources. ● Not robust. Subsystem must fail if it cannot find required service.
Proposal 3: Treat services as subsystems - Peer to Peer	**For:** ● Peer to peer relationship between subsystems/services more flexible. All the same advantages as proposal II.

Capturing rationale: record and replay

- Participants use a semi-structured notation to record meetings and online discussions
- Can use a issue-base or text-based conventions

Advantages

- **Captures arguments**
- **Occurs closely with the design**

Disadvantages

- **Requires post processing**
- **Can disrupt the design process**

Example: capturing rationale in meetings

- Facilitator posts an agenda
- Participants respond to the agenda
- Facilitator updates the agenda and facilitates the meeting
- Minute taker records the meeting

Example: capturing rationale in meetings (2)

- Facilitator posts an agenda
  - **Discussion items are *issues***
- Participants respond to the agenda
  - **Proposed amendments are *proposals* or additional *issues***
- Facilitator updates the agenda and facilitates the meeting
  - **The scope of each discussion is a single *issue* tree**
- Minute taker records the meeting
  - **The minute taker records discussions in terms of *issues*, *proposals*, *arguments*, and *criteria*.**
  - **The minute taker records decisions as *resolutions* and *action items*.**

Example: database discussion agenda

3. Discussion

I[1] Which policy for retrieving tracks from the database**?**

I[2] Which encoding for representing tracks in transactions**?**

I[3] Which query language for specifying tracks in the database request**?**

Example: database discussion

I[1] Which policy for retrieving tracks from the database?

Jim: How about we just retrieve the track specified by the query? It is straightforward to implement and we can always revisit it if it is too slow.

Ann: Prefetching neighboring tracks would not be much difficult and way faster.

Sam: During route planning, we usually need the neighbor tracks anyway. Queries for route planning are the most common queries.

Jim: Ok, let's go for the prefetch solution. We can revert to the simpler solution if it gets too complicated.

Example: database discussion minutes

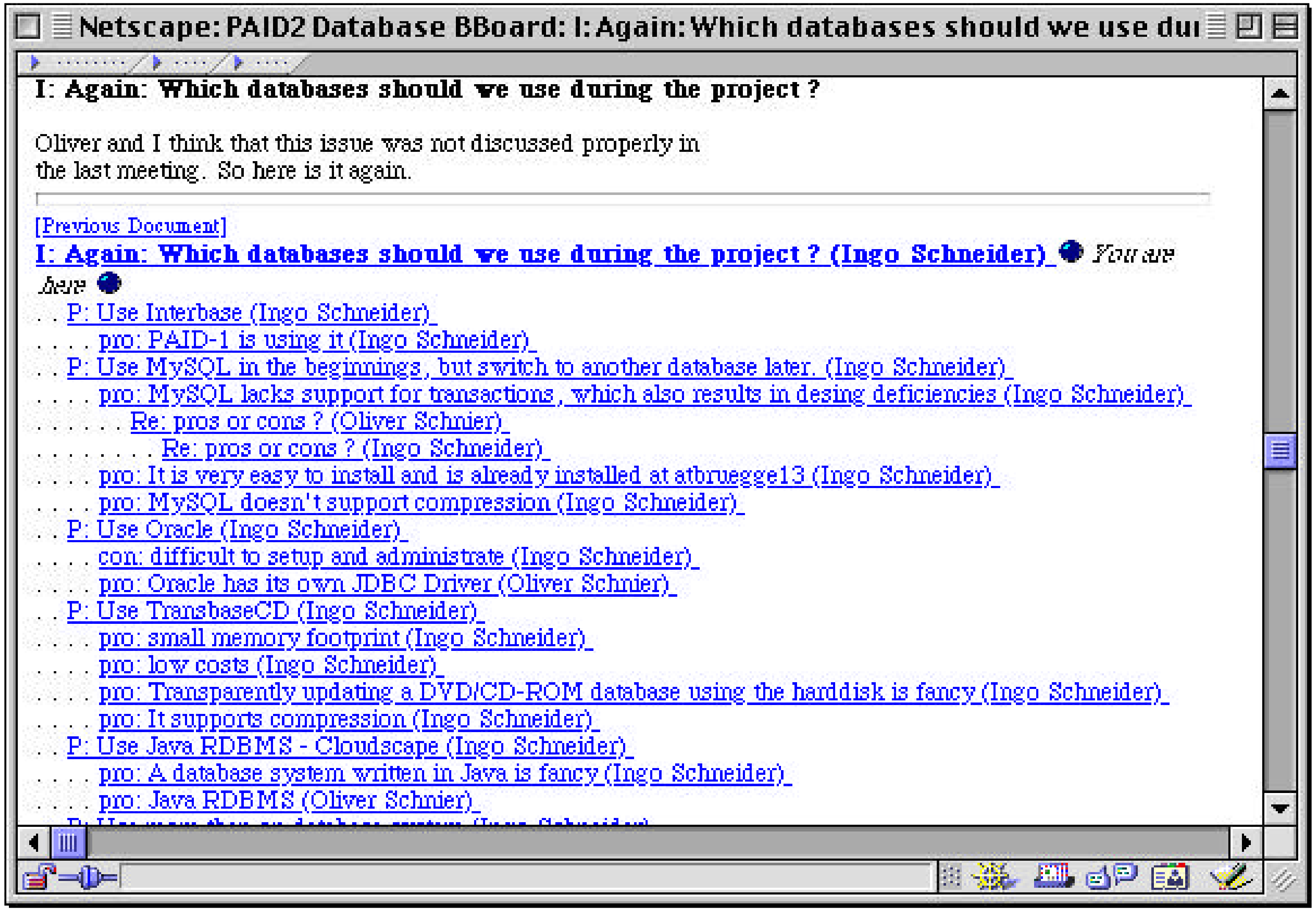
3. Discussion

```
I[1] Which policy for retrieving tracks from the database?
  P[1.1] Single tracks!
       A- Lower throughput.
       A+ Simpler.
  P[1.2] Tracks + neighbors!
       A+ Overall better performance: during route
       planning, we need the neighbors anyway.
  {ref: 1/31 routing meeting}
R[1] Implement P[1.2]. However, the prefetch should be
  implemented in the database layer, allowing use to
  encapsulate this decision. If all else fails, we will
  fall back on P[1.1].
```

Maintaining rationale

- Rationale information grows as the system evolves.
- Rationale information needs to be updated to be useful.
- An issue base can be used to maintain the issue trees.
- The meeting agendas and minutes should be integrated with the issue base.

Example: Lotus Notes IBIS Discuss



Netscape: PAID2 Database BBoard: I: Again: Which databases should we use dur

I: Again: Which databases should we use during the project ?

Oliver and I think that this issue was not discussed properly in
the last meeting. So here is it again.

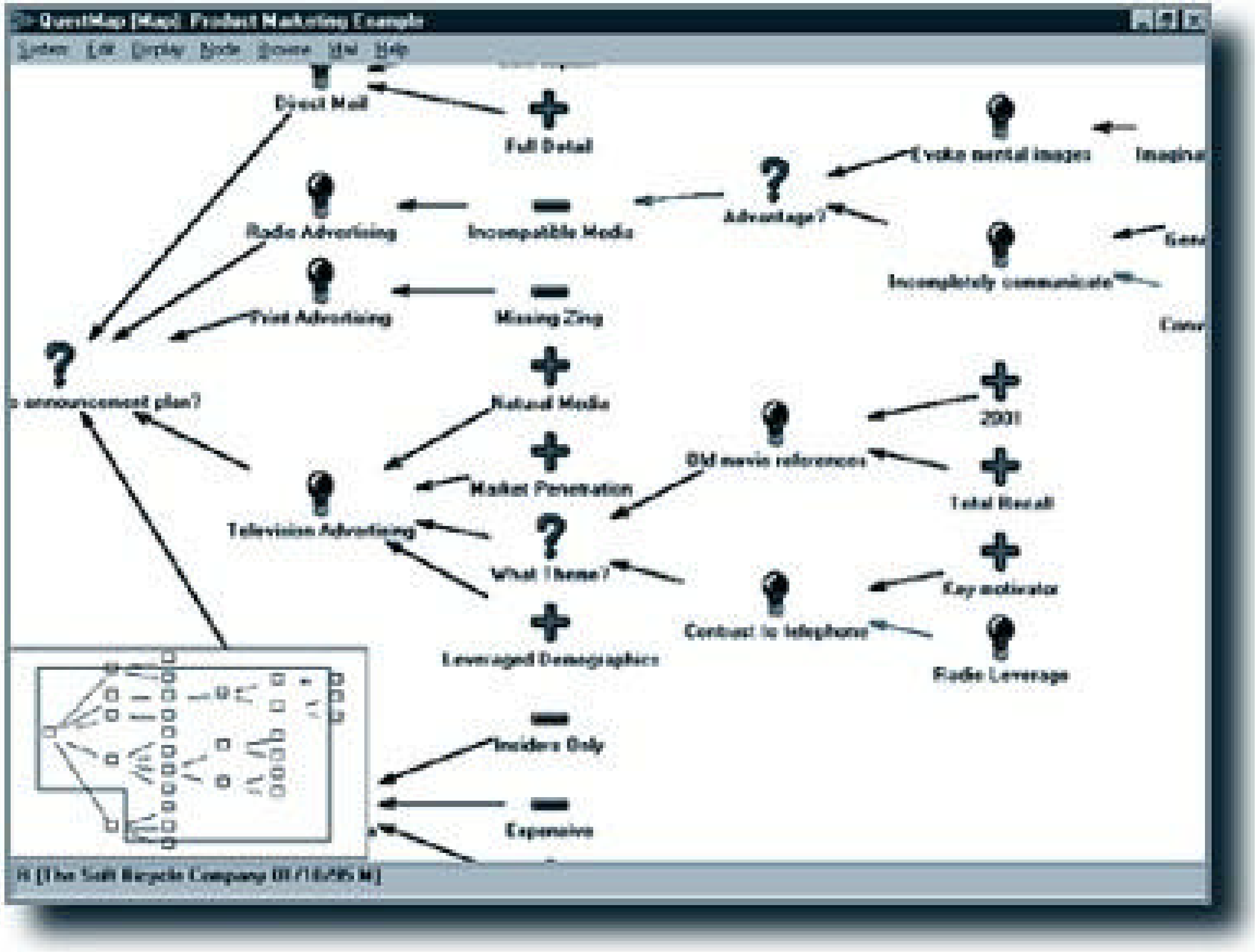
[Previous Document]

I: Again: Which databases should we use during the project ? (Ingo Schneider) ● *You are here* ●

. . P: Use Interbase (Ingo Schneider)
. . . . pro: PAID-1 is using it (Ingo Schneider)
. . P: Use MySQL in the beginnings, but switch to another database later. (Ingo Schneider)
. . . . pro: MySQL lacks support for transactions, which also results in desing deficiencies (Ingo Schneider)
. . . . . . Re: pros or cons ? (Oliver Schnier)
. . . . Re: pros or cons ? (Ingo Schneider)
. . . . pro: It is very easy to install and is already installed at atbruegge13 (Ingo Schneider)
. . . . pro: MySQL doesn't support compression (Ingo Schneider)
. . P: Use Oracle (Ingo Schneider)
. . . . con: difficult to setup and administrate (Ingo Schneider)
. . . . pro: Oracle has its own JDBC Driver (Oliver Schnier)
. . P: Use TransbaseCD (Ingo Schneider)
. . . . pro: small memory footprint (Ingo Schneider)
. . . . pro: low costs (Ingo Schneider)
. . . . pro: Transparently updating a DVD/CD-ROM database using the harddisk is fancy (Ingo Schneider)
. . . . pro: It supports compression (Ingo Schneider)
. . P: Use Java RDBMS - Cloudscape (Ingo Schneider)
. . . . pro: A database system written in Java is fancy (Ingo Schneider)
. . . . pro: Java RDBMS (Oliver Schnier)

Rationale in practice

- QuestMap, by the Soft Bicycle Company



Open issues

- Formalizing knowledge is costly.
  - **Maintaining a consistent design model is expensive.**
  - **Capturing and maintaining rationale is worse.**
- The benefits of rationale are perceived to be long term.
  - **If the person who does the work is not the one who benefits from it, the work will have lower priority.**
  - **90% of off-the-shelf software projects are terminated before the product ships.**
- Capturing rationale can be disruptive.
  - **Developers are reluctant to stop design to explain what they just did.**

Rationale in the future

- As with many new methods and technologies, will appear as features of existing tools, rather than self contained tools.
- Examples:
  - **Discussion support in** RequisitePro**, tool for requirements analysis of Rational**
  - **Complex schema for modeling change requests in** ClearQuest **and** ClearCase**, a configuration tool by Rational**
  - **Discussion in REQuest, tool for requirements elicitation, explicitly supports a rationale-based method**
- In the longer term, issue models or discussion models of multiple tools would be integrated into one issue-base.

Rationale summary

- Capturing rationale is critical:
  - **argumentation of alternatives,**
  - **explicit design criteria,**
  - **consensus building, and**
  - **information relevant for future modifications.**
- Issue models
  - **offer a structured solution to capture rationale**
  - **make it easier to find rationale information**
- Open issues
  - **Integration of rationale with current development tools (e.g., communication, IDEs, CASE)**
  - **Cost-effectiveness**
  - **Developer incentives**