Setting up the presentation:

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Plan, Repair, Execute, Explain

How Planning Helps to Assemble your Home Theater

Pascal Bercher and Susanne Biundo and Thomas Geier and Thilo Hörnle and Florian Nothdurft* and Felix Richter and Bernd Schattenberg

Institute of Artificial Intelligence
Institute of Communications Engineering*

June 26th, 2014

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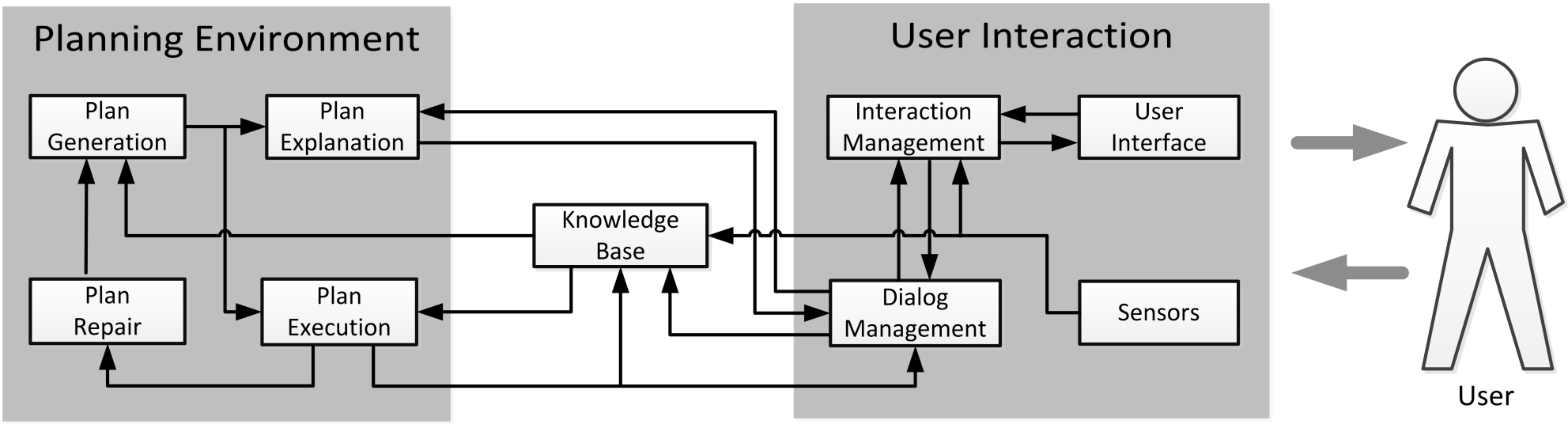
Provide advanced user assistance based on:

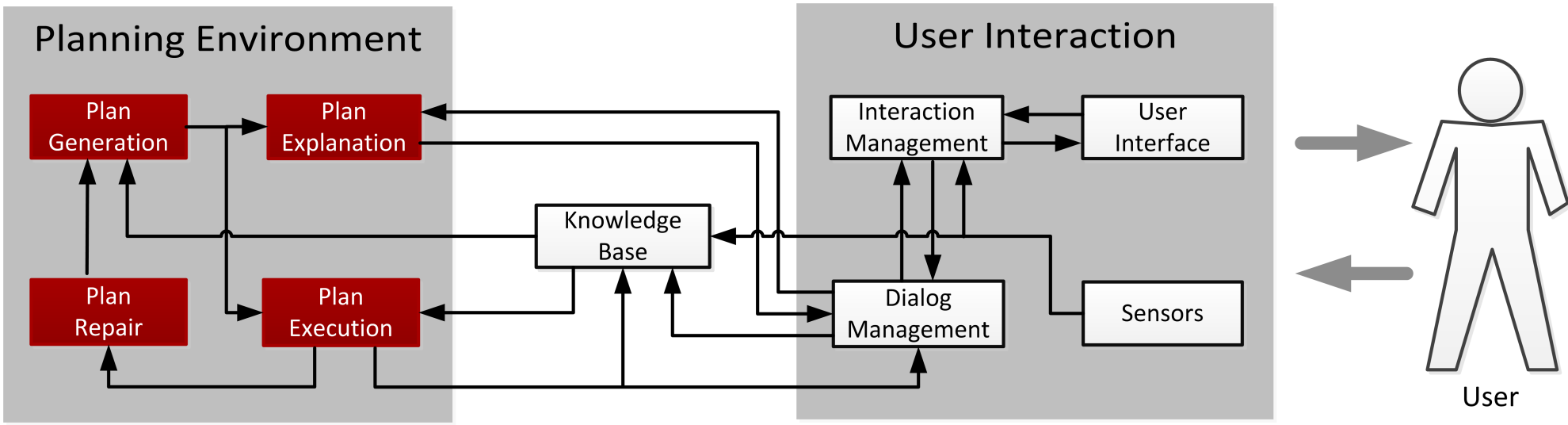
- *user-centered* planning:
  plan generation, execution, repair, explanation
- user interaction:
  dialog and interaction management

Example domain:

- set up a complex home theater

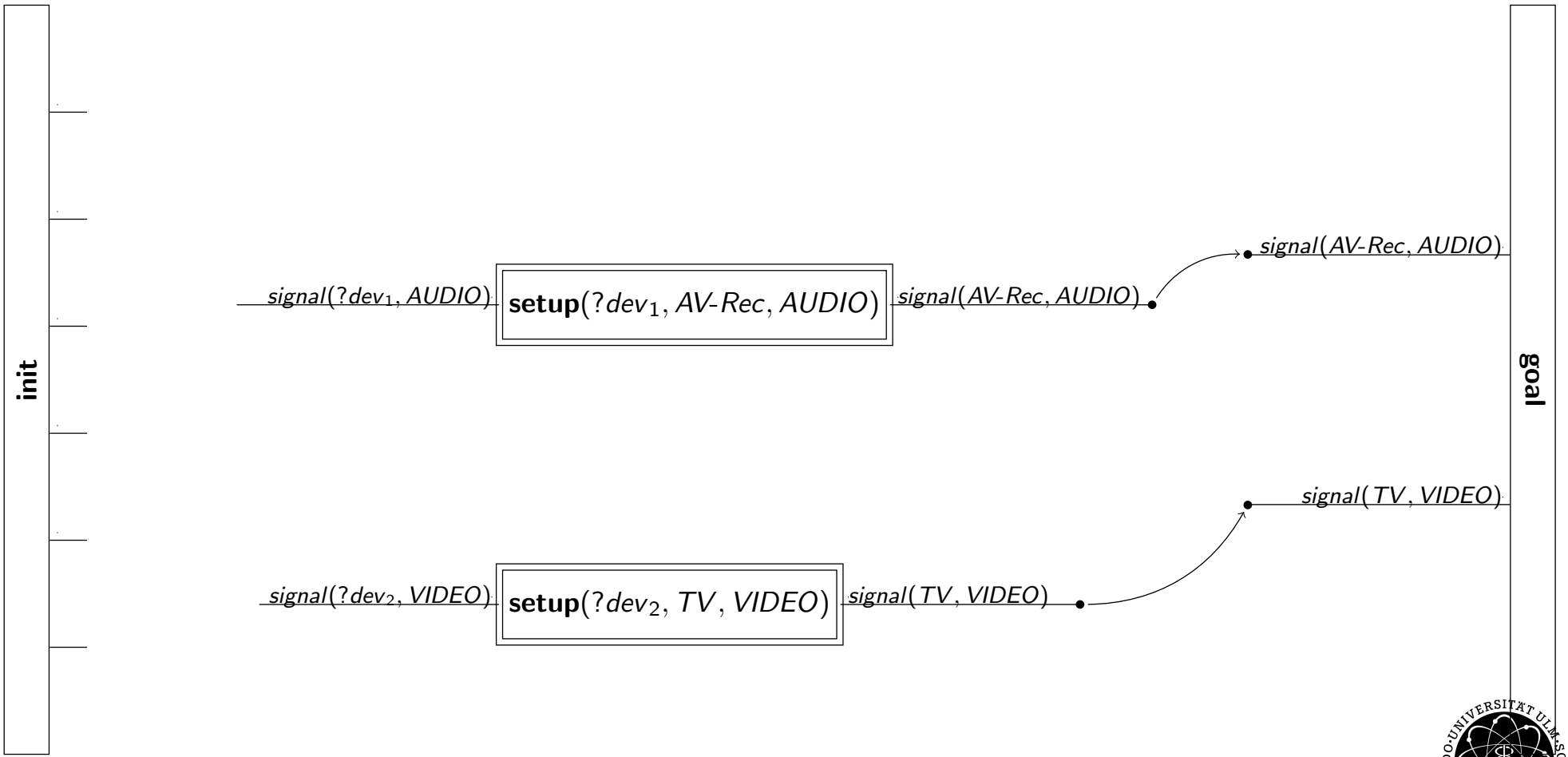
The Assembly Task:

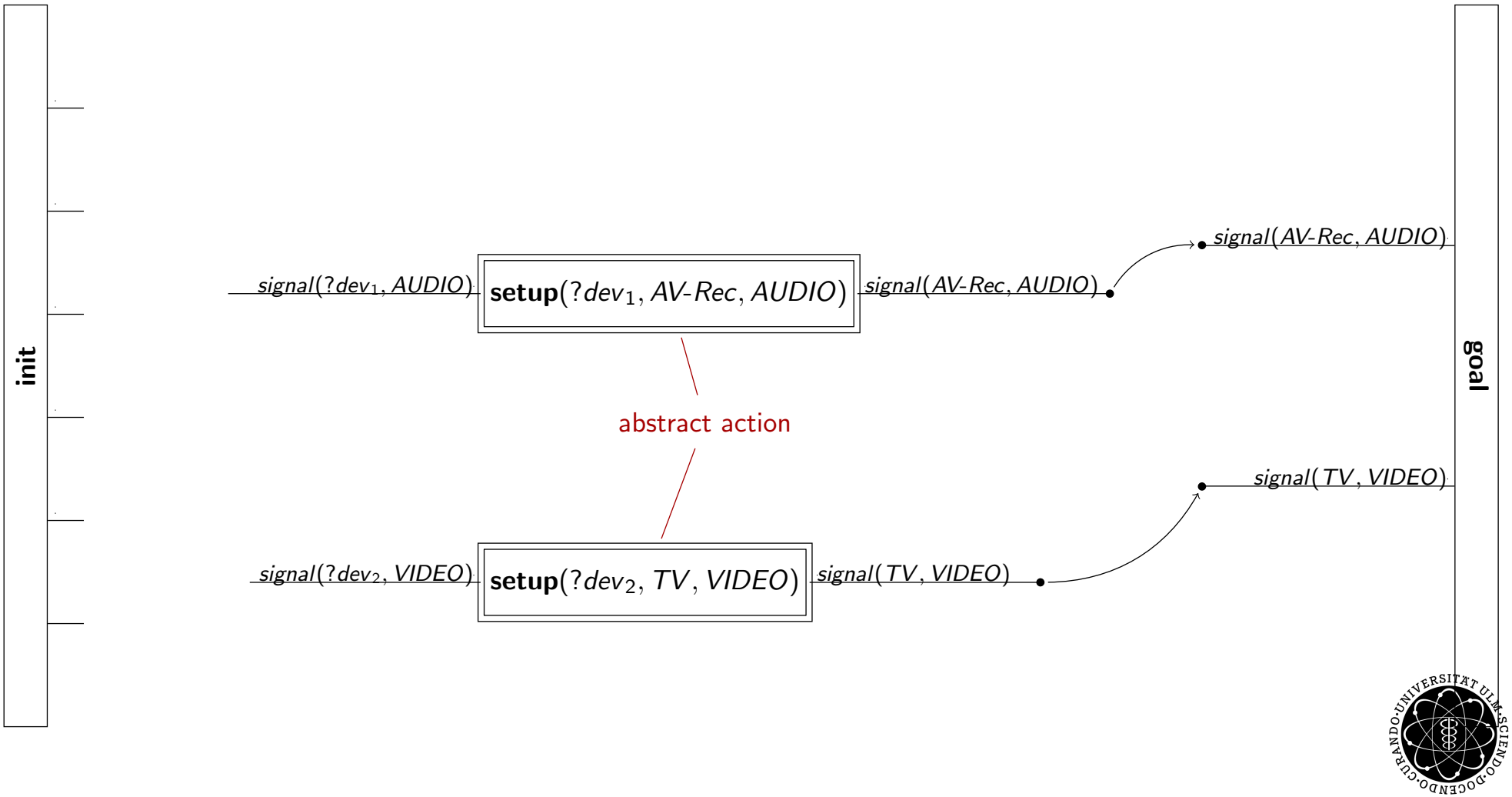

Planning Environment
Plan Generation
Plan Explanation
Knowledge Base
Plan Repair
Plan Execution
User Interaction
Interaction Management
User Interface
Dialog Management
Sensors
User

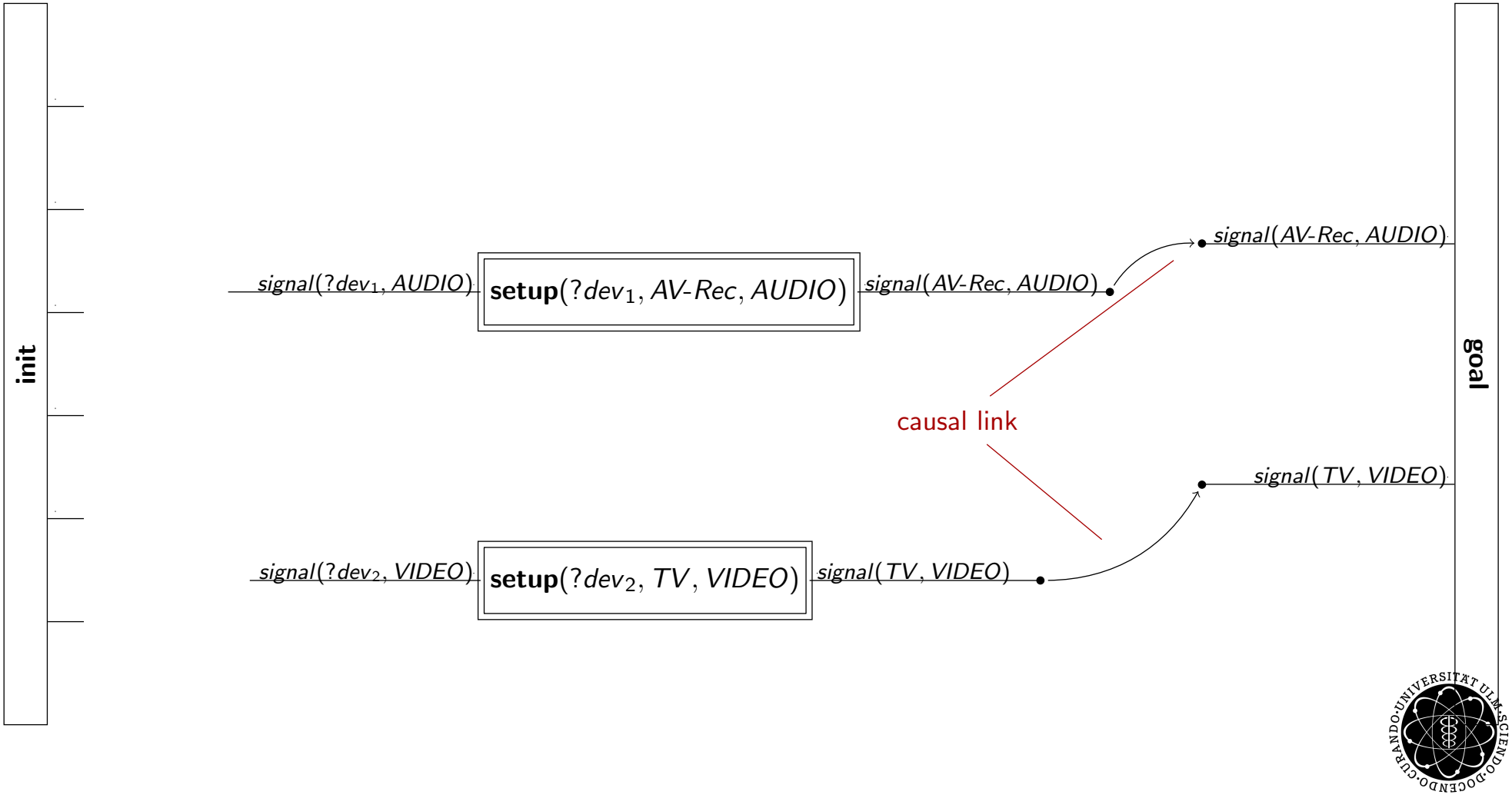

Planning Environment
Plan Generation
Plan Explanation
Knowledge Base
Plan Repair
Plan Execution
User Interaction
Interaction Management
User Interface
Dialog Management
Sensors
User

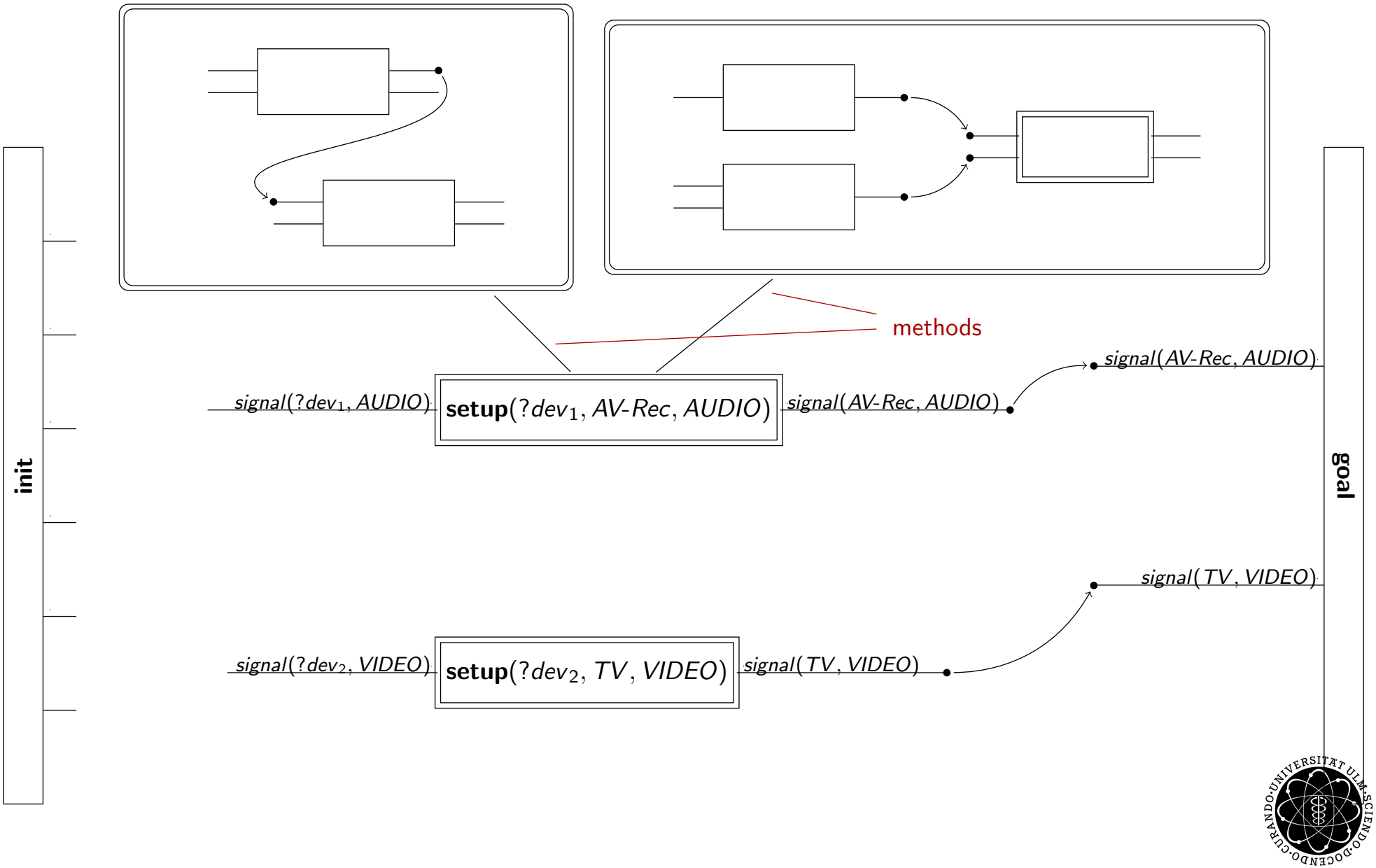
Hybrid Planning:

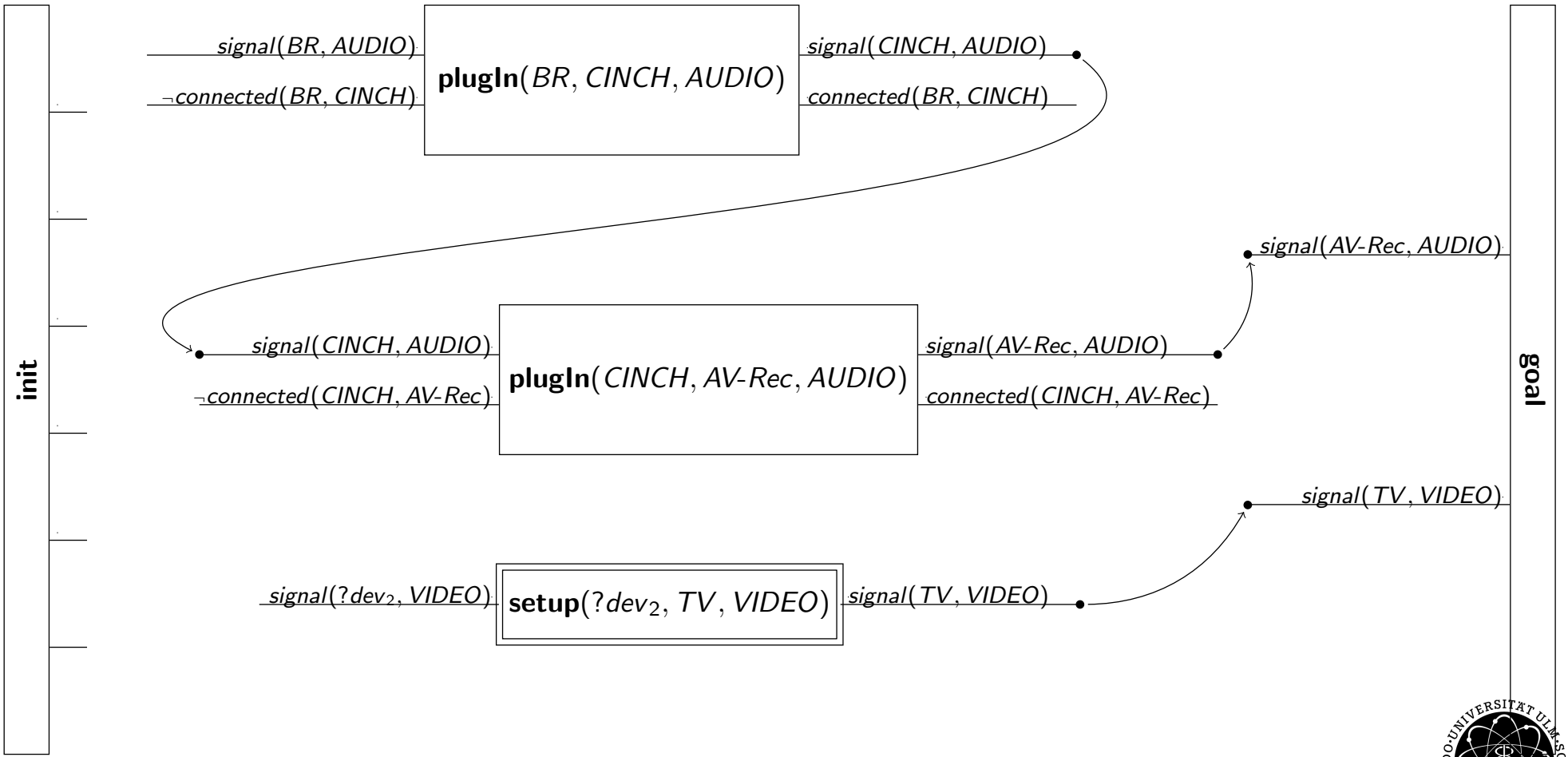
- approach fusing Hierarchical Task Network (HTN) Planning with Partial-Order Causal-Link (POCL) Planning
- search in the space of partial plans
- refine the initial partial plan until it is executable

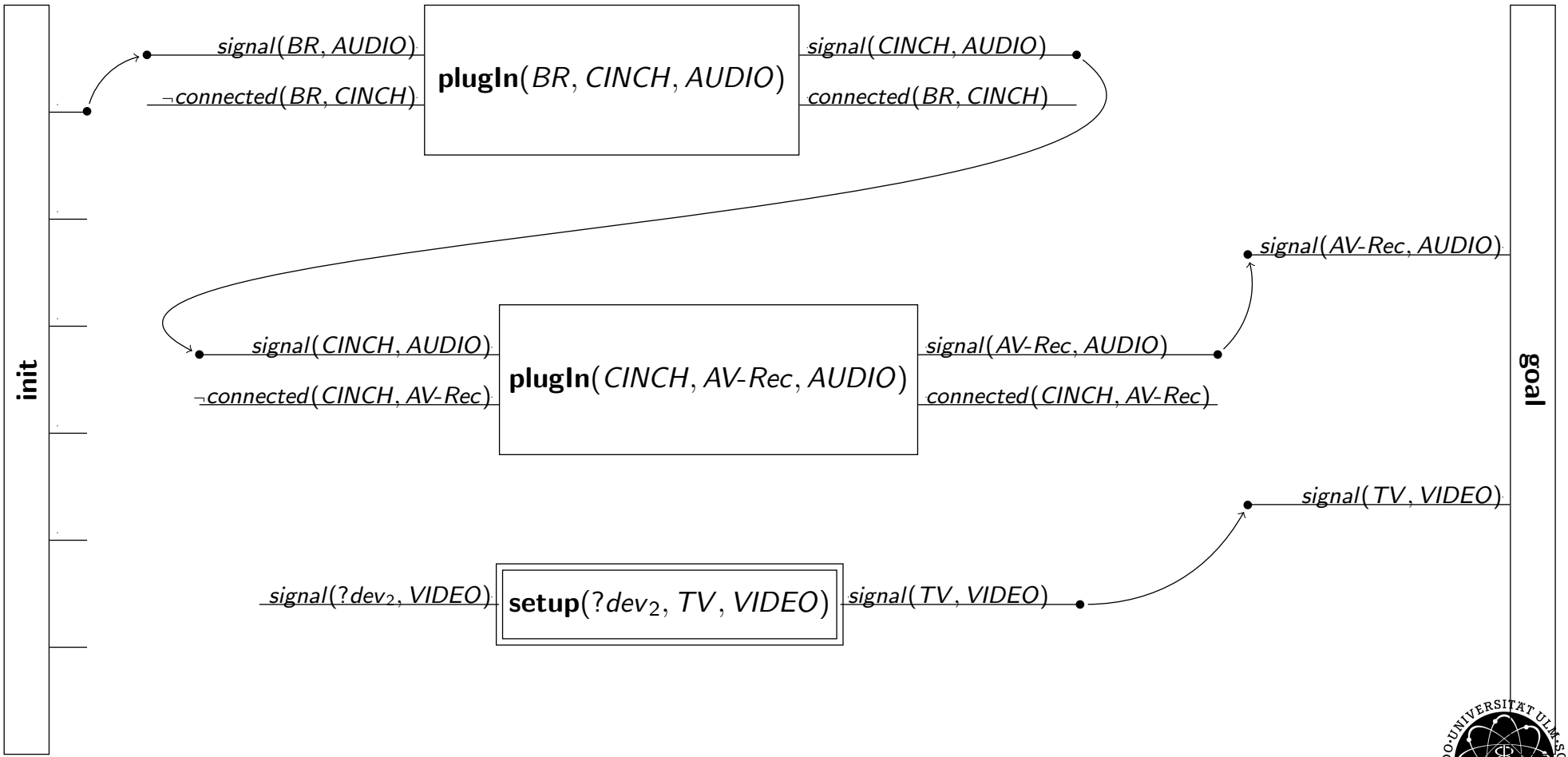

init
goal
signal(?dev1, AUDIO)
setup(?dev1, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
signal(TV, VIDEO)

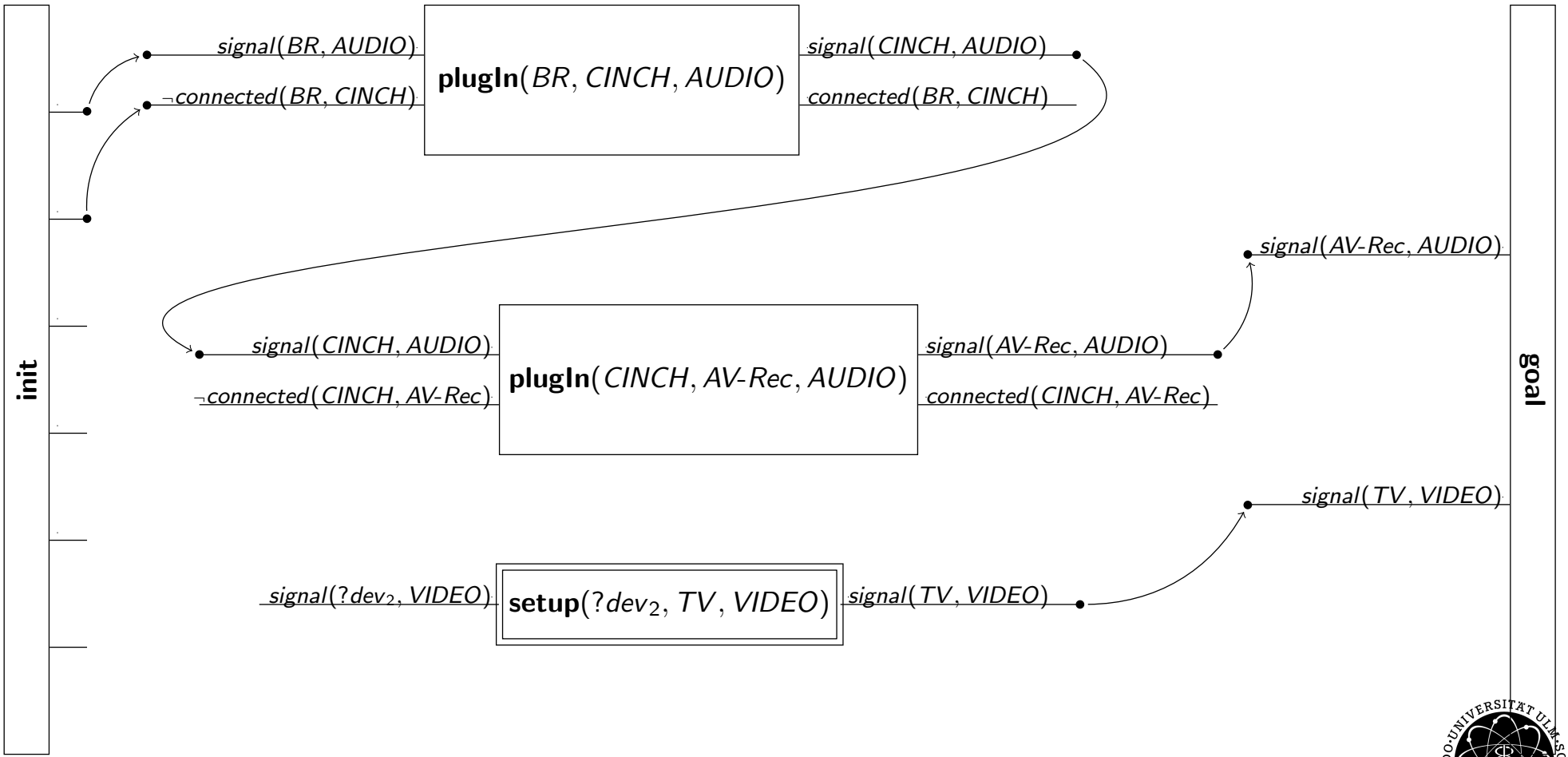

init
goal
signal(?dev1, AUDIO)
setup(?dev1, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
abstract action
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
signal(TV, VIDEO)

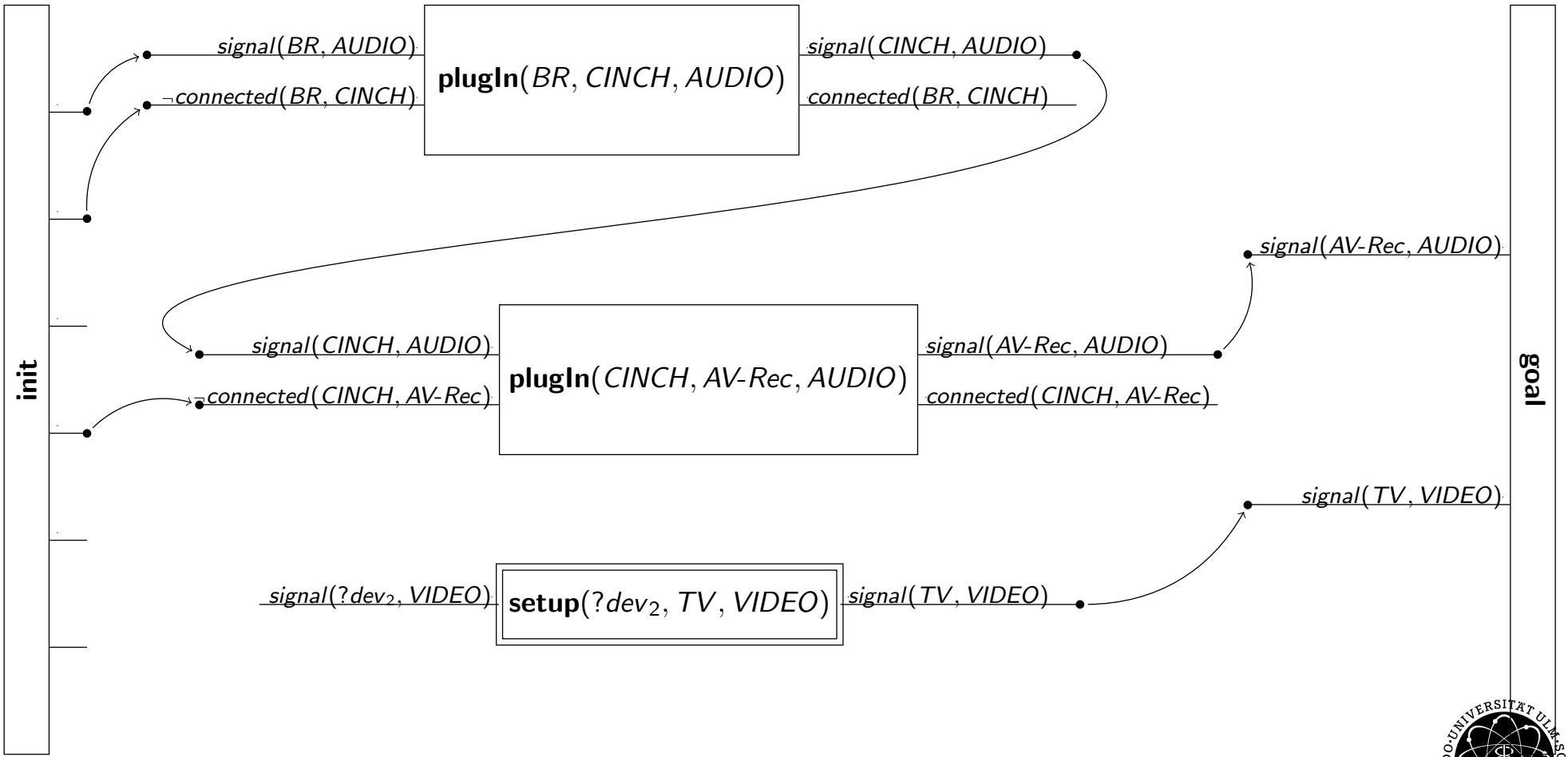

init
goal
signal(?dev1, AUDIO)
setup(?dev1, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
causal link
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
signal(TV, VIDEO)

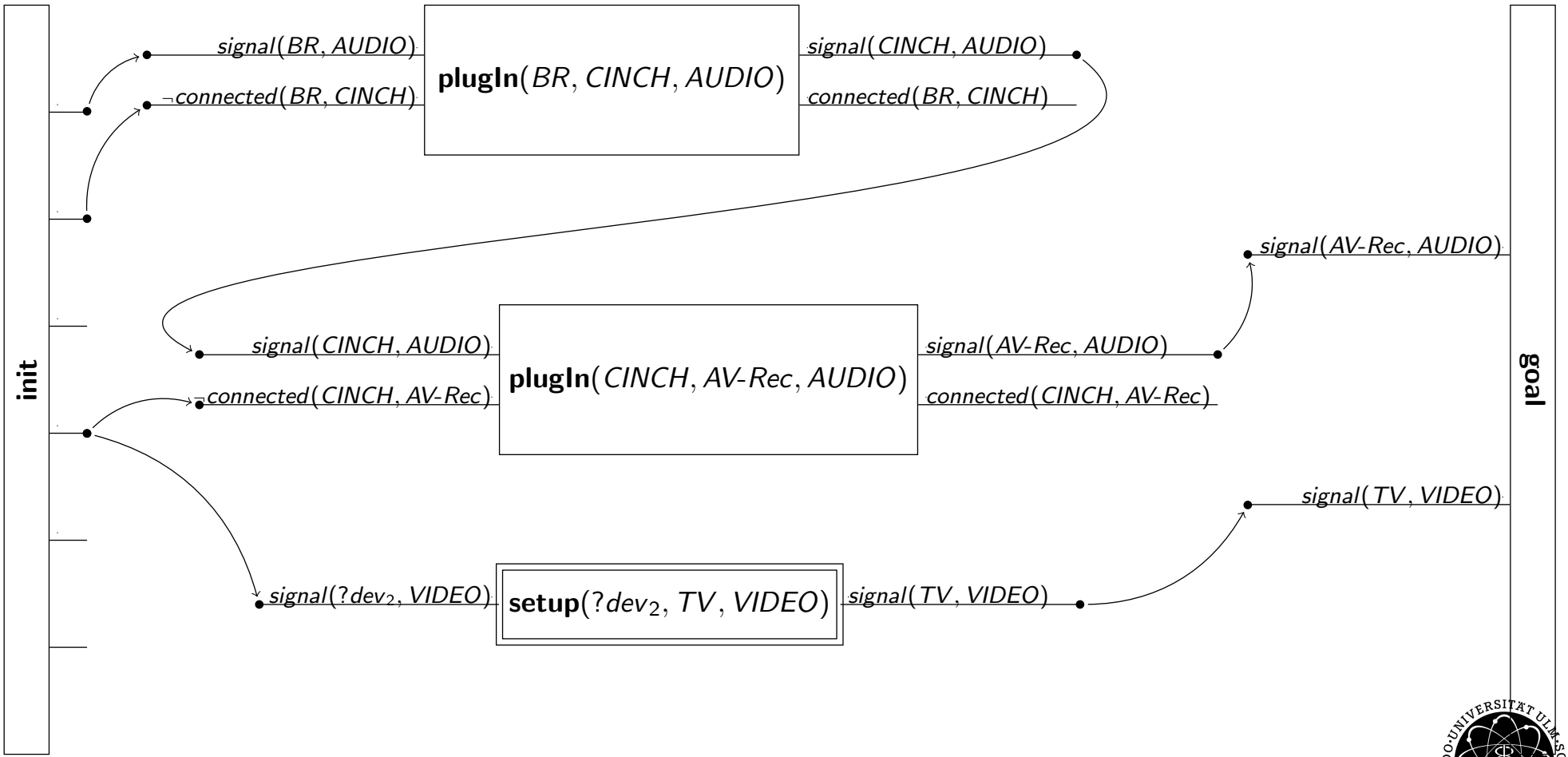

init
goal
methods
signal(?dev1, AUDIO)
setup(?dev1, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
signal(TV, VIDEO)

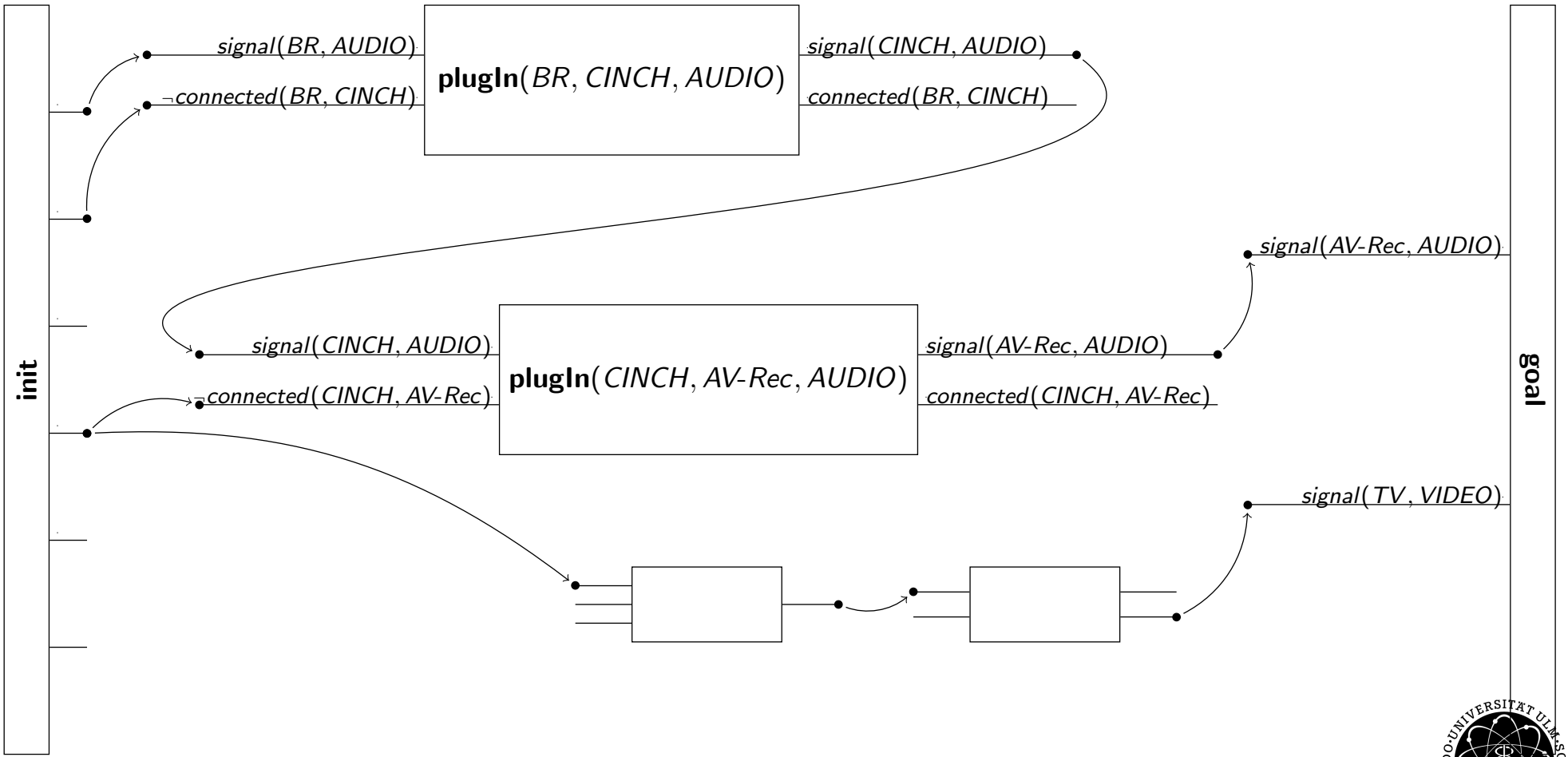

init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
goal

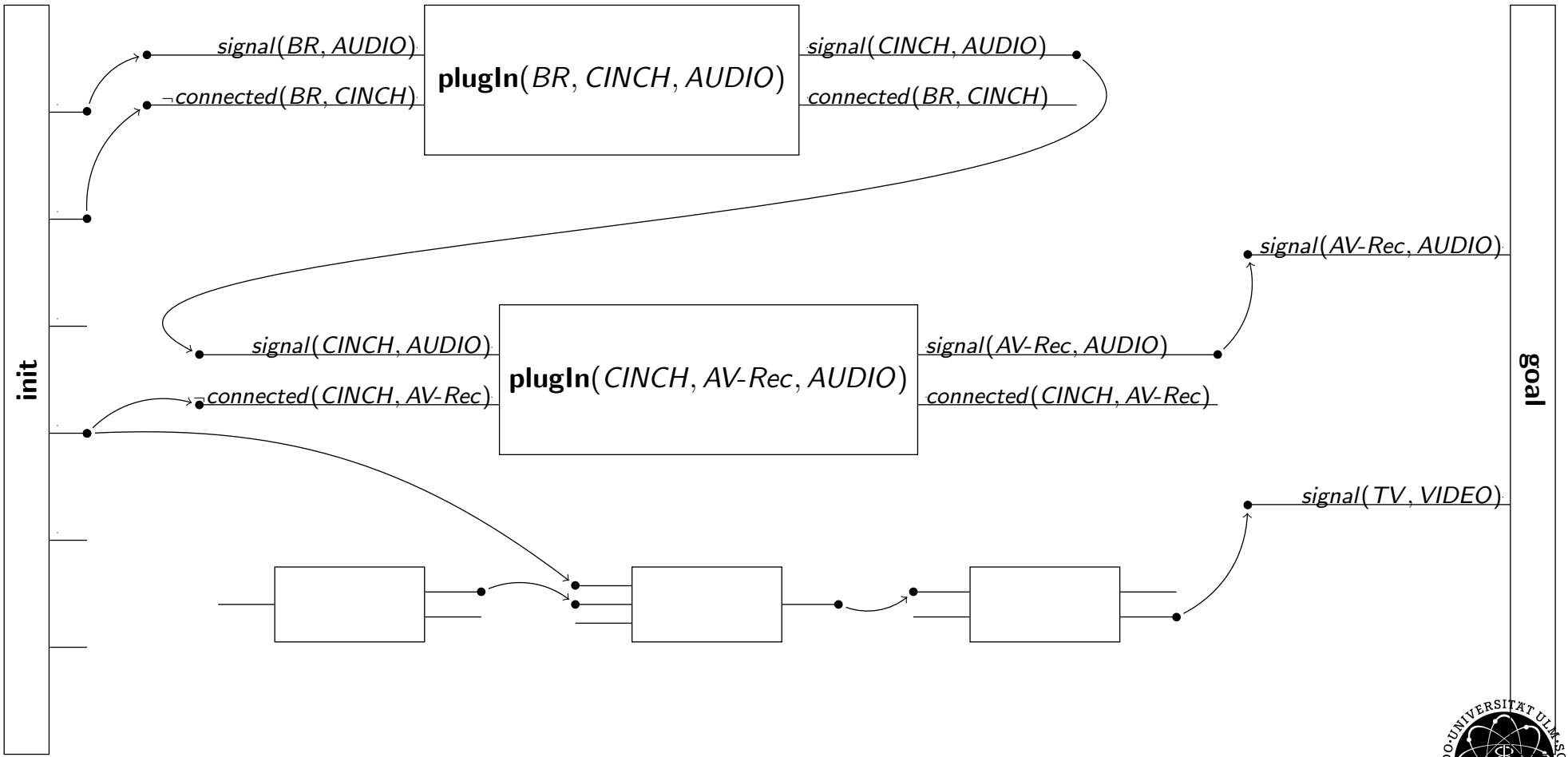

init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
goal

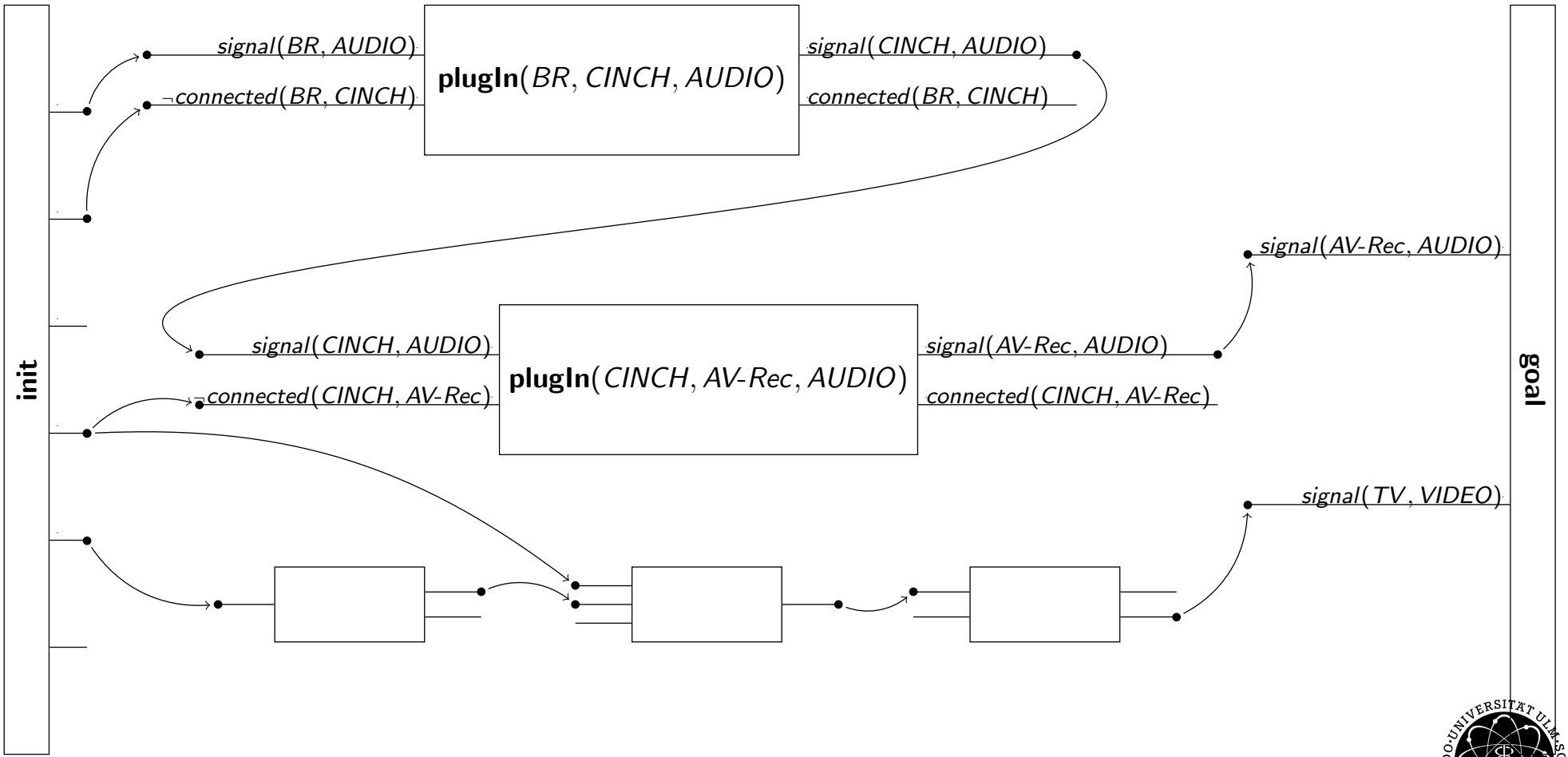

init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
goal

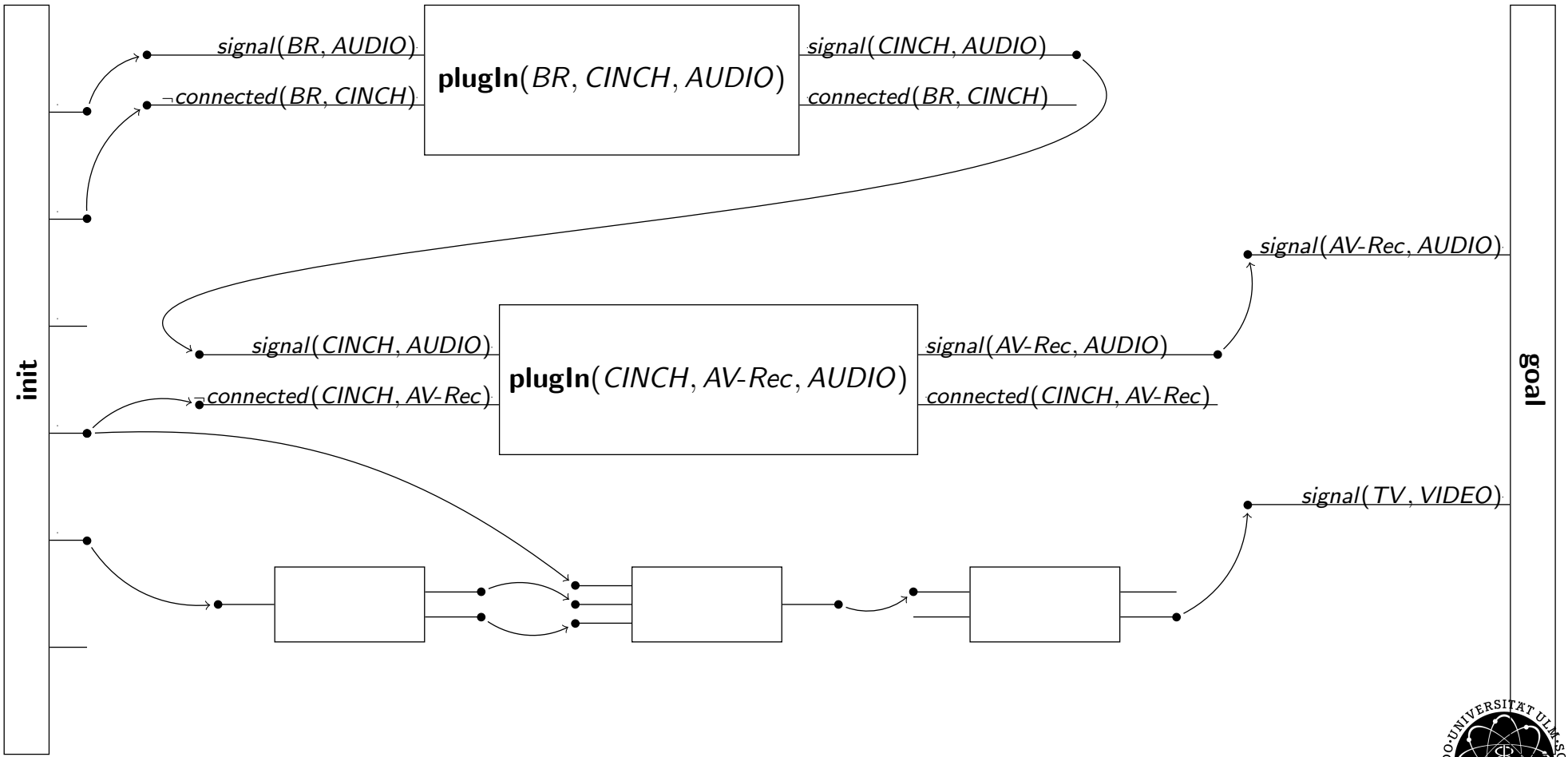

init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
goal

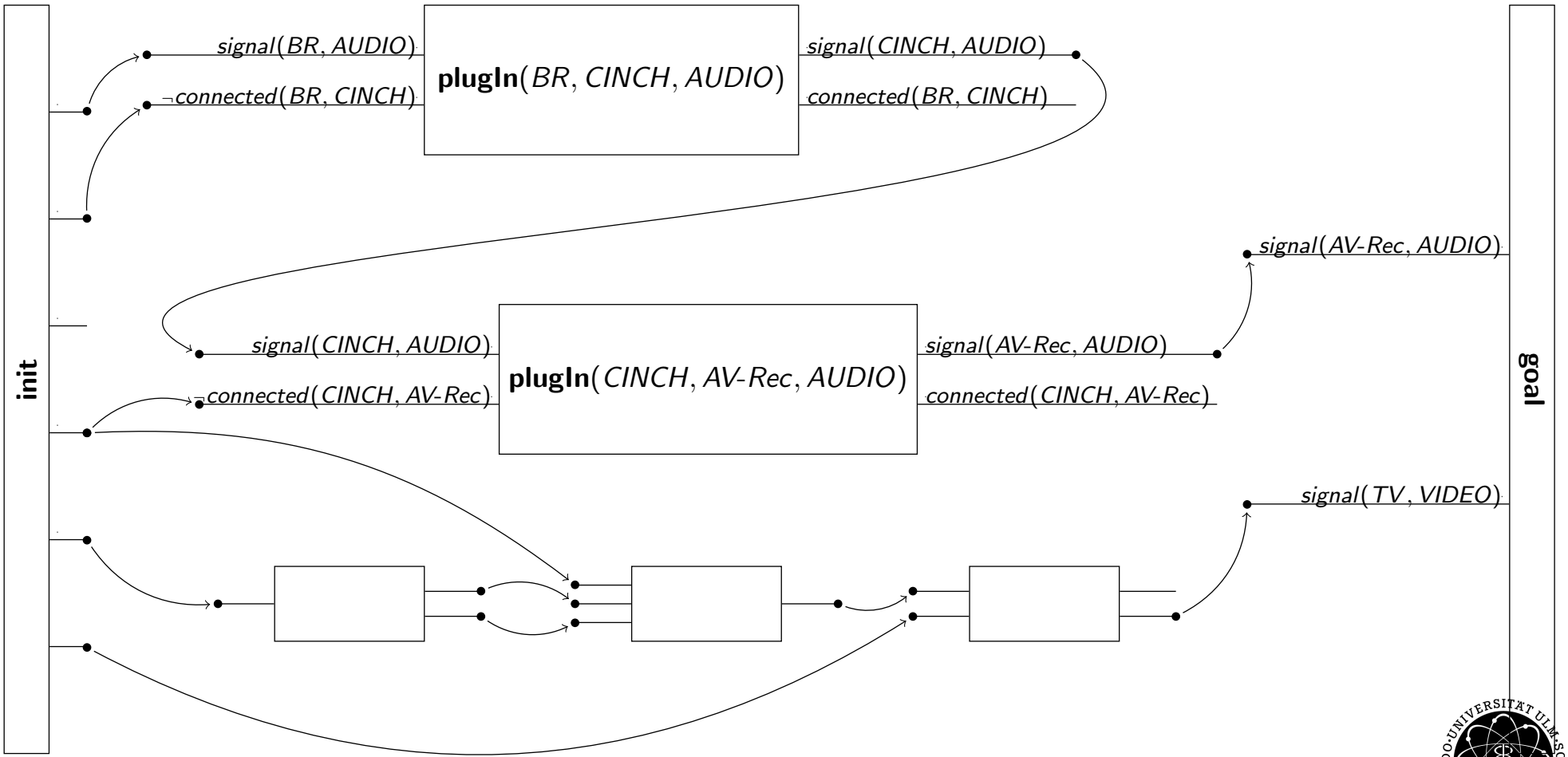

init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
goal


init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
goal


init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
goal

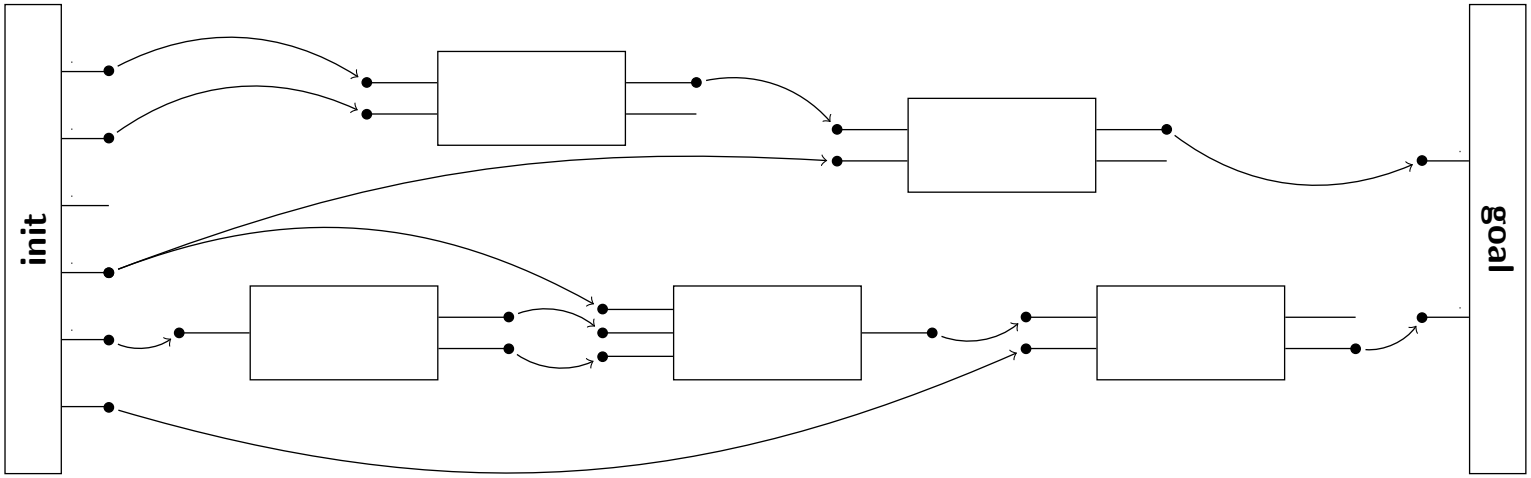

init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
goal


init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
goal


init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
goal

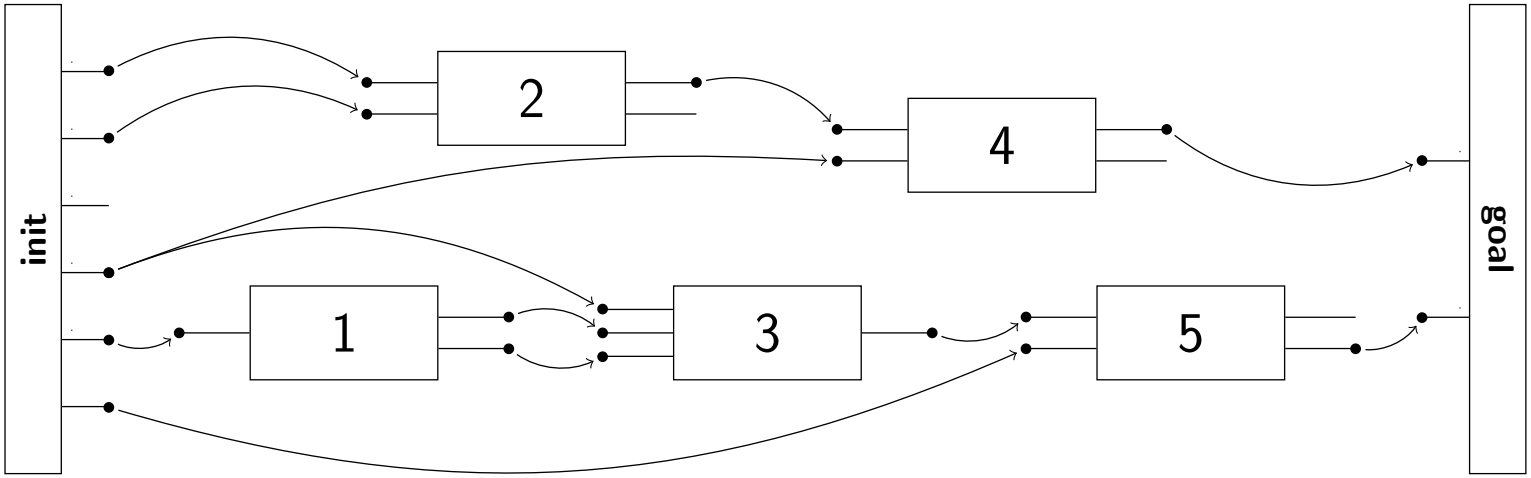
communicate solution plan to the user:

- generate a plausible linearization of the actions



communicate solution plan to the user:

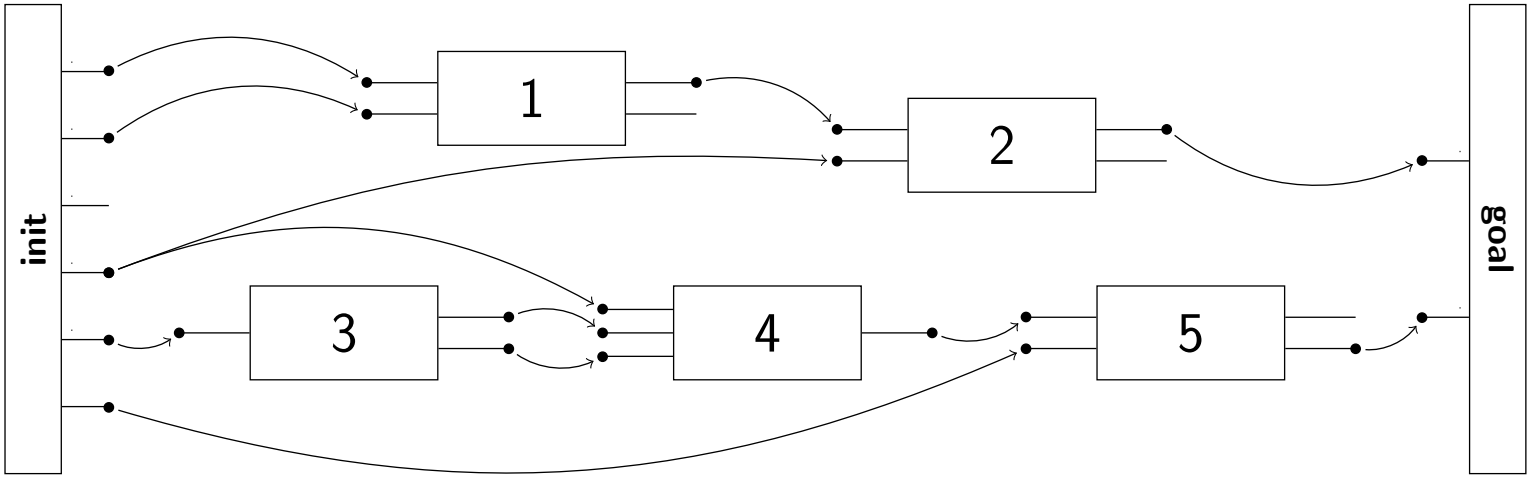
- generate a plausible linearization of the actions



1: connect ...
2: connect CINCH cable (the first end) with Blu-ray player
3: connect ...
4: connect CINCH cable (the other end) with AV receiver
5: connect ...

communicate solution plan to the user:

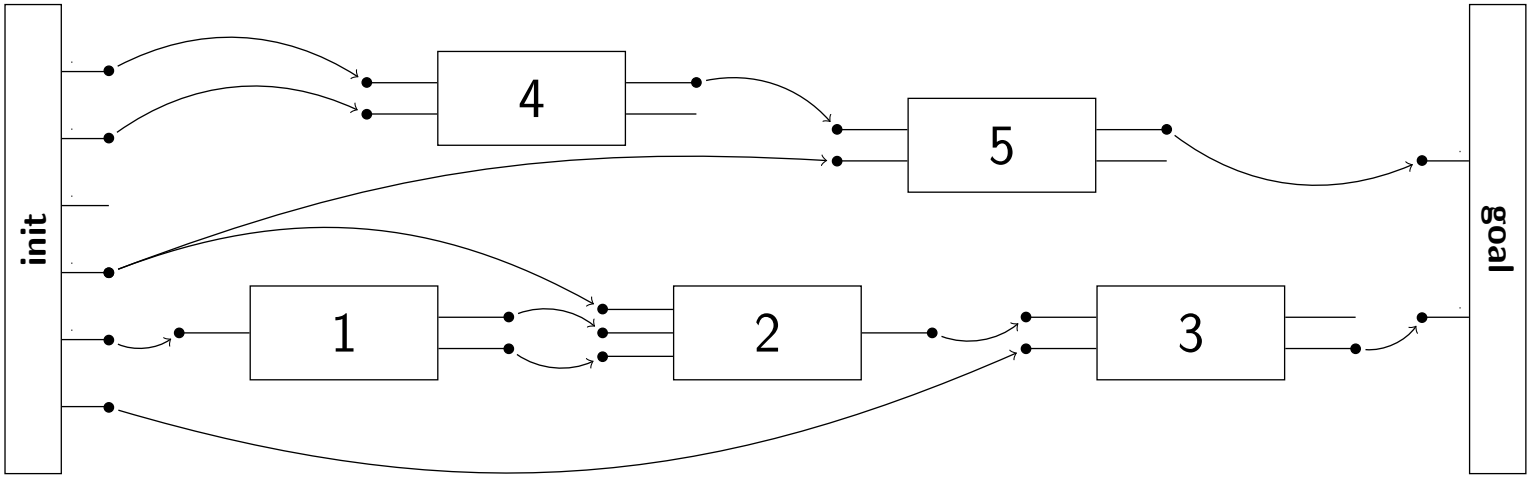
- generate a plausible linearization of the actions



1: connect CINCH cable (the first end) with Blu-ray player
2: connect CINCH cable (the other end) with AV receiver
3: connect ...
4: connect ...
5: connect ...

communicate solution plan to the user:

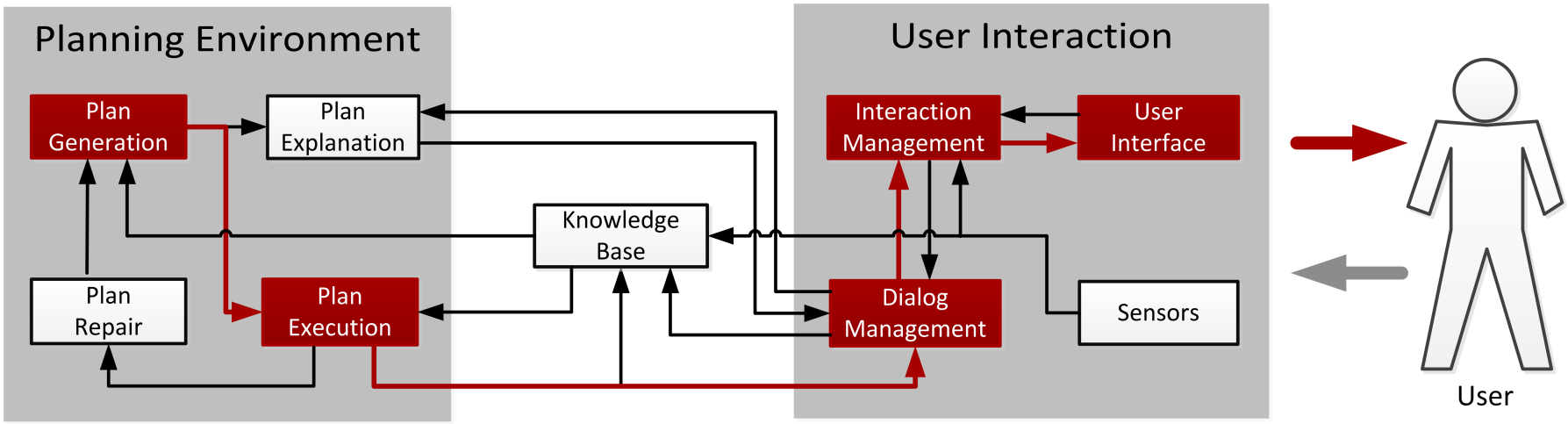
- generate a plausible linearization of the actions



1: connect . . .
2: connect . . .
3: connect . . .
4: connect CINCH cable (the first end) with Blu-ray player
5: connect CINCH cable (the other end) with AV receiver

communicate solution plan to the user:

- present the solution plan action by action
- display each primitive action in an adequate manner
  - load dialog model for each action
  - display dialog according to interaction management



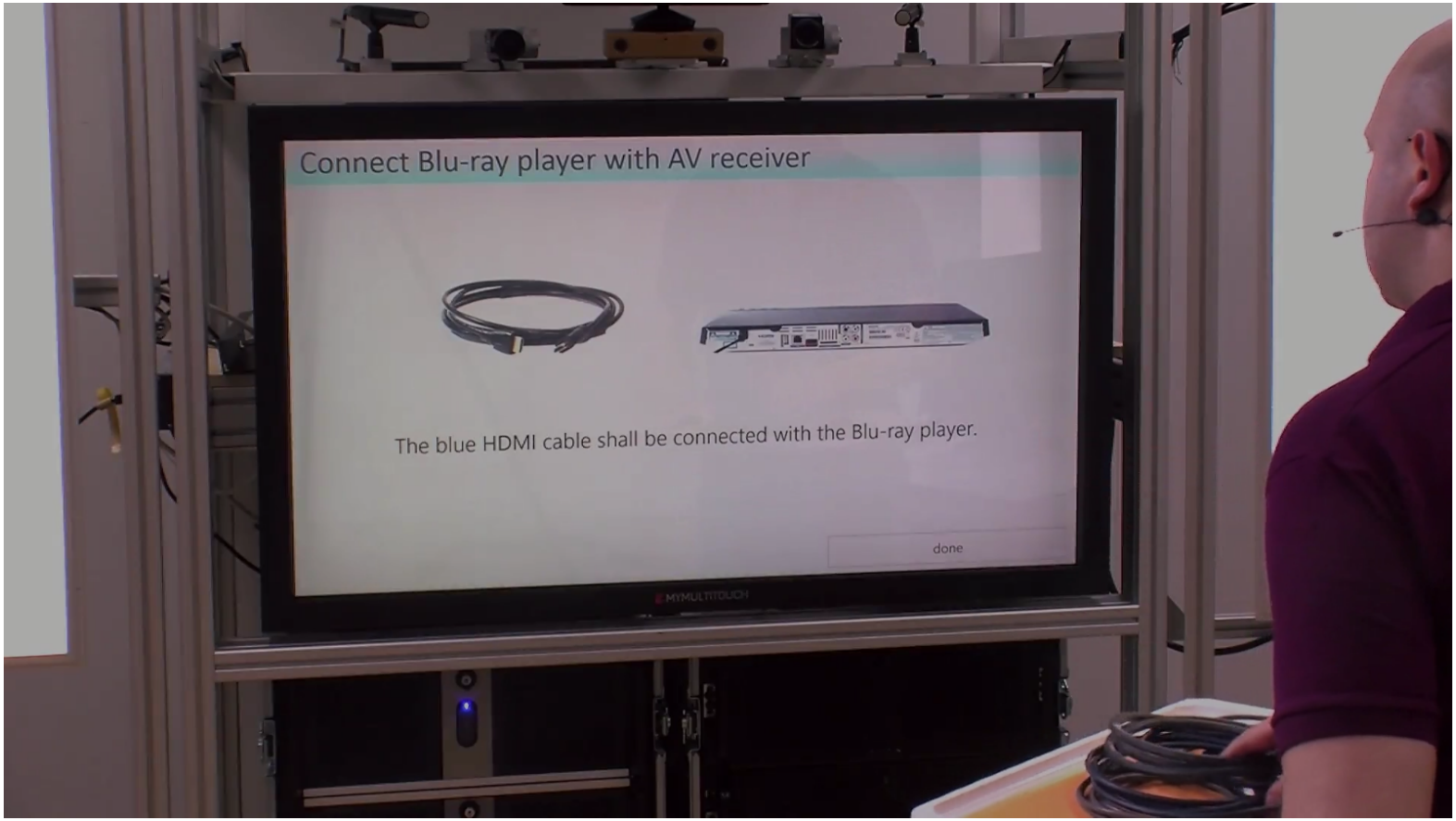

The SCART end of the SCART to cinch cable shall be connected with
the satellite receiver as depicted.
done

Plan execution fails if:

- current world state differs from expected world state
- in our example: *broken(HDMI)* vs. $\neg$*broken(HDMI)*

Repair procedure:

- already executed actions must occur in new solution
- unexpected state changes are represented by an ad-hoc generated additional action (so-called process)


Connect Blu-ray player with AV receiver
The blue HDMI cable shall be connected with the Blu-ray player.
done

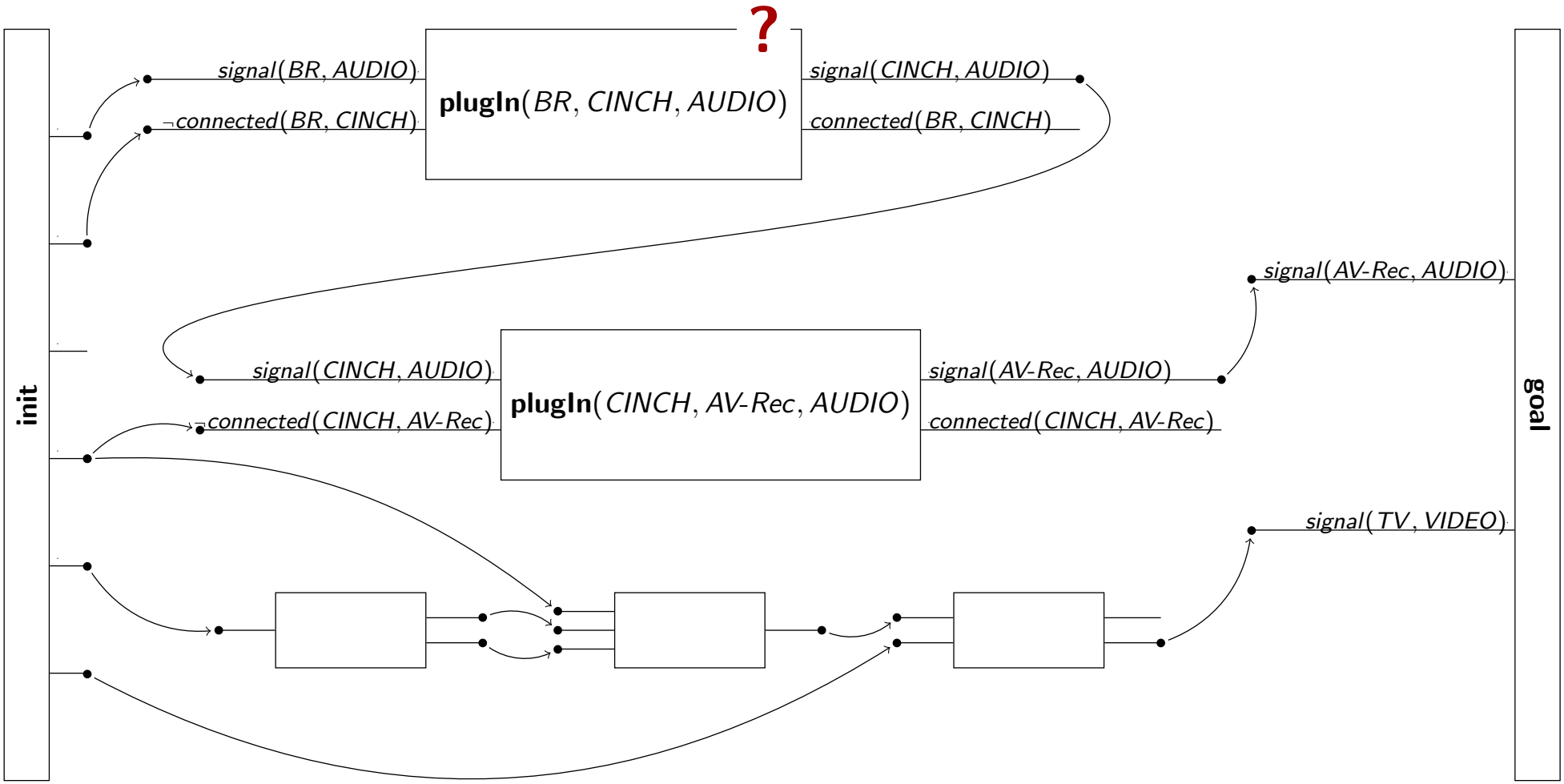
Question: Why is that action necessary for my task?

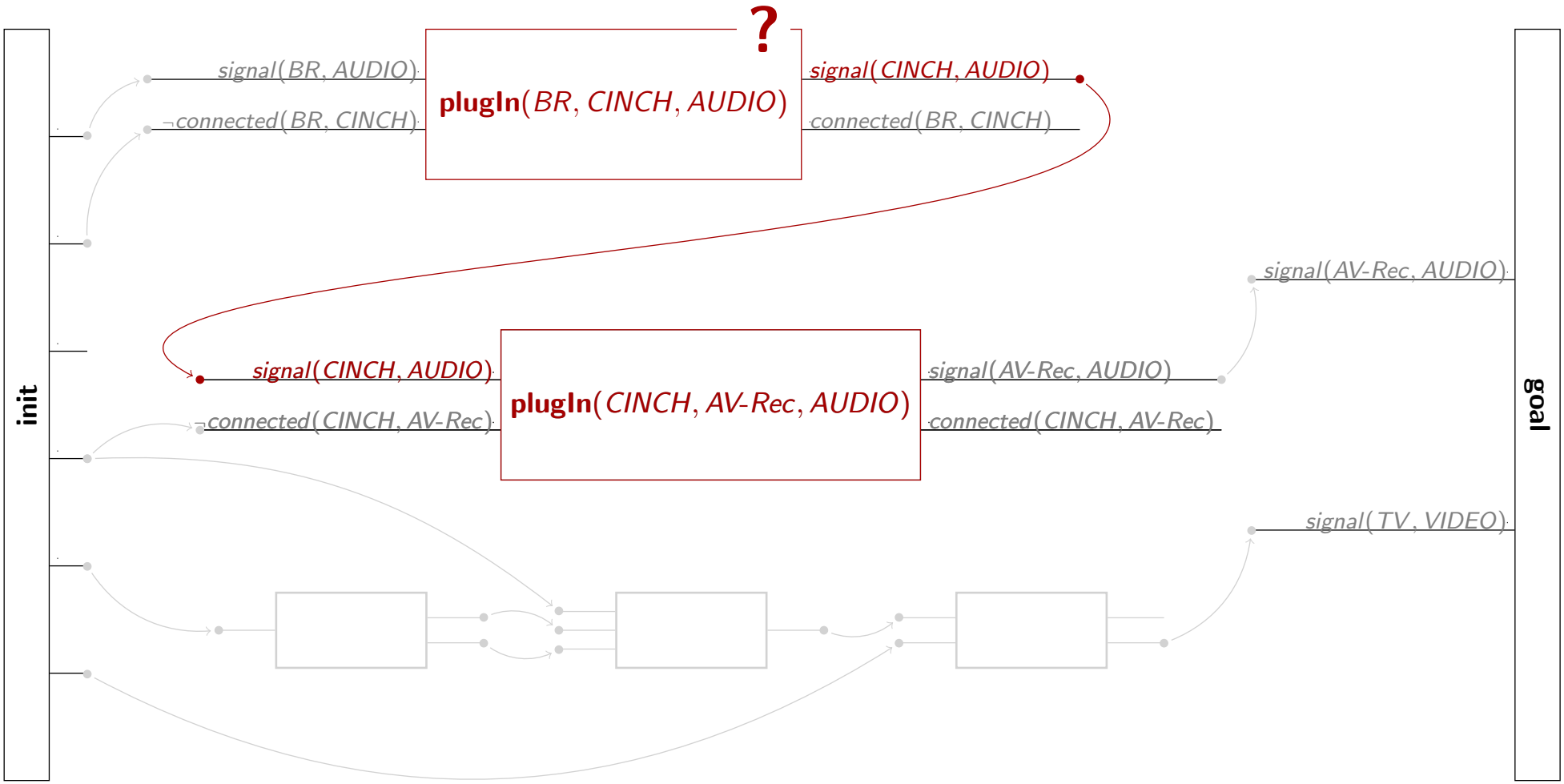
Explanations in natural language are generated from (raw) proofs in an axiomatic system based on:

- the solution plan's causal structure (causal links)
- the decomposition hierarchy

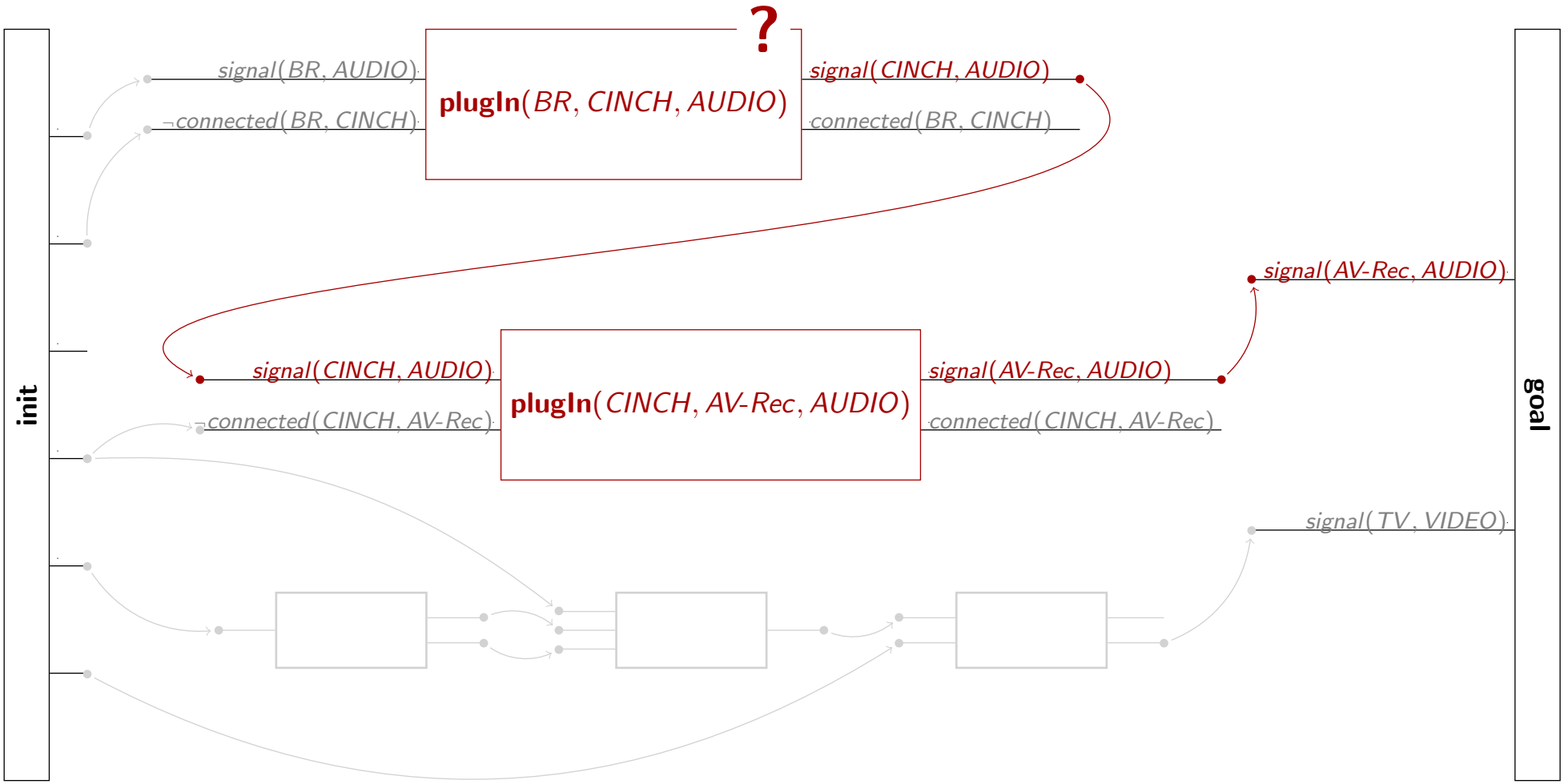
Example axioms:

- $\forall$ actions $a_1, a_2 : CR(a_1, a_2) \wedge N(a_2) \Rightarrow N(a_1)$
- $N(\textbf{goal})$

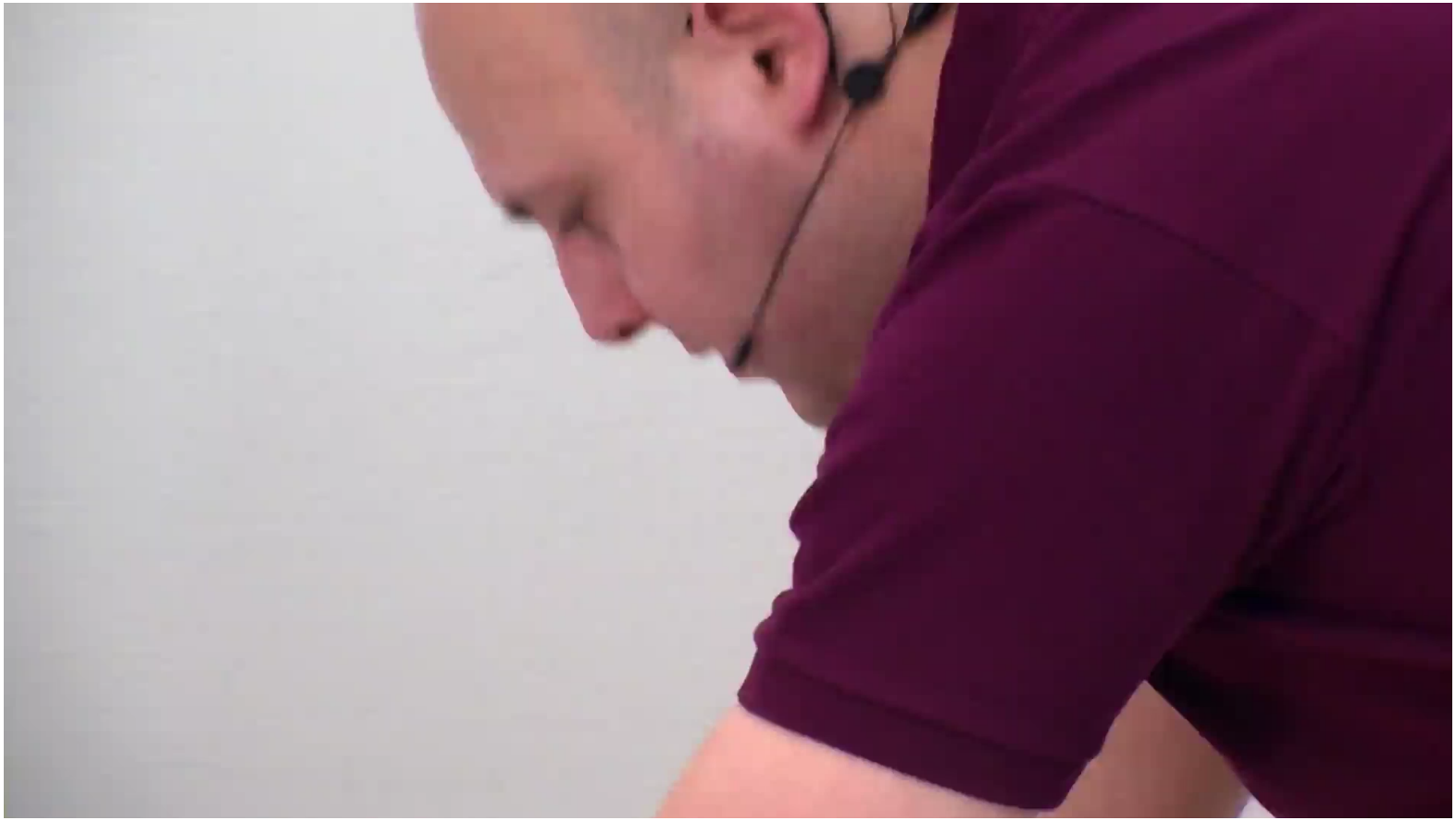

?
init
signal(BR, AUDIO)
¬connected(BR, CINCH)
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AV-Rec, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AV-Rec)
plugIn(CINCH, AV-Rec, AUDIO)
signal(AV-Rec, AUDIO)
connected(CINCH, AV-Rec)
signal(TV, VIDEO)
goal



CR(**plugIn**(*BR*, *CINCH*, *AUDIO*) , **plugIn**(*CINCH*, *AV-Rec*, *AUDIO*)) ∧
N(**plugIn**(*CINCH*, *AV-Rec*, *AUDIO*))
⇒ N(**plugIn**(*BR*, *CINCH*, *AUDIO*))



CR(**plugIn**(*CINCH*, *AV-Rec*, *AUDIO*), **goal**) ∧
N(**goal**)
⇒ N(**plugIn**(*CINCH*, *AV-Rec*, *AUDIO*))

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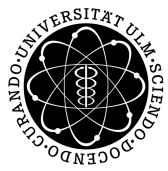
We evaluated:

- the general acceptance of such an assistance system
- the impact of plan explanation:

  does plan explanation foster the user's confidence in correctness of solution?



- assembly task:
  - television needs video signals
  - AV receiver needs audio signals
- subjects were given a solution plan on an iPad and asked to follow the instructions
- experiment is designed as controlled, randomized trial with 59 subjects in two groups
  - treatment group was presented a plan explanation for two fixed actions
  - control group only received that instruction

Hypothesis:

- subjects were asked to rate their confidence that the presented solution plan is correct, i.e., solves the task
- mean/sd confidence on a 5-point Likert scale:
  4.50/0.82 (treatment), 4.66/0.55 (control)
  (the difference is not statistically significant)
- confidence was already very high

General findings:

- device and port photographs often mentioned positively
- high correlation between the overall perception and the self-rated skills (people considering themselves unskilled liked the system better)
- women liked the system better than men
- people with higher educational level liked the explanation better

Some positive remarks by subjects:

- “assists in a useful way”
- “this assistant would be great for my parents”
- “the explanations seem to be unnecessary at first glance, but they increase the understanding of what one does and strengthen the credibility of the system”

Main Results:

- developed architecture providing user assistance
- it integrates *user-centered* planning capabilities:
  plan generation, execution, repair, explanation
- it integrates planning with user interaction
- user study shows acceptance and usefulness of intelligent user assistance

Video available at **http://www.sfb-trr-62.de/**

Subjects of empirical user study:

- $\leq$ 30 years: 19 female, 27 male
- $\geq$30 years: 3 female, 7 male
- (age not reported for three subjects)
- 26 subjects had university degree, 9 were doing their Ph.D
- 7 subjects' degree was less than high school
- 30 subjects had technical or mathematical background: computer science/engineering, natural science, mathematics