Finding User-friendly Linearizations of Partially Ordered Plans

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Provide advanced user assistance based on:

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

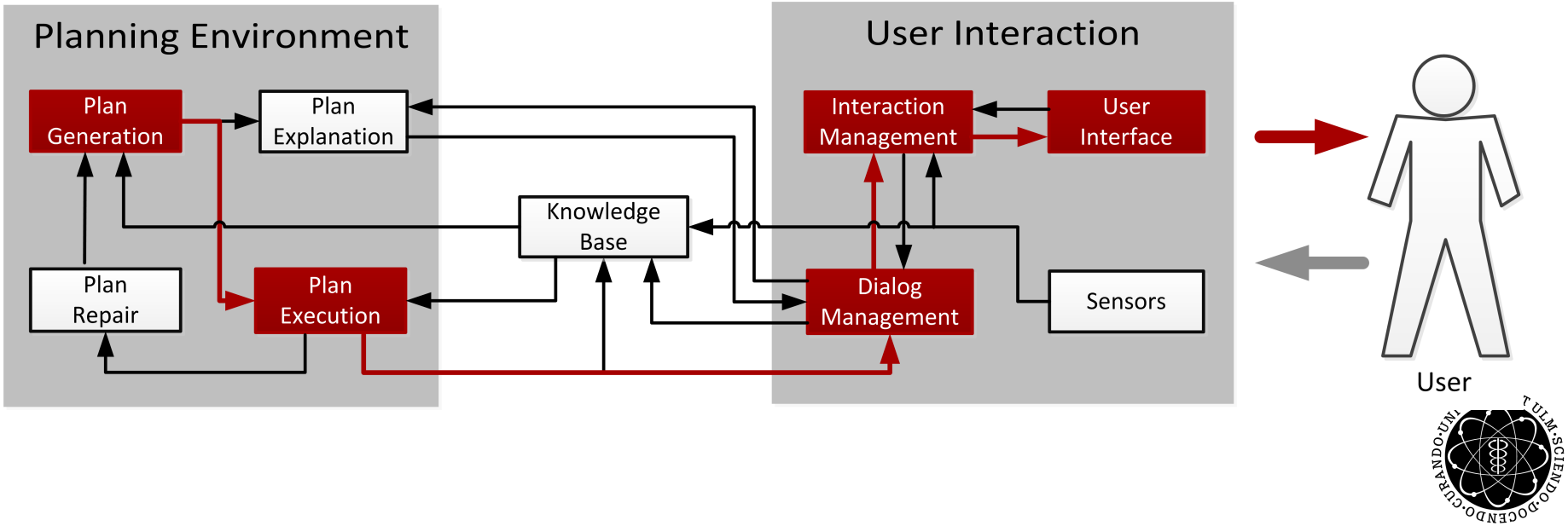
Example domain:

- set up a complex home theater

The Assembly Task:

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

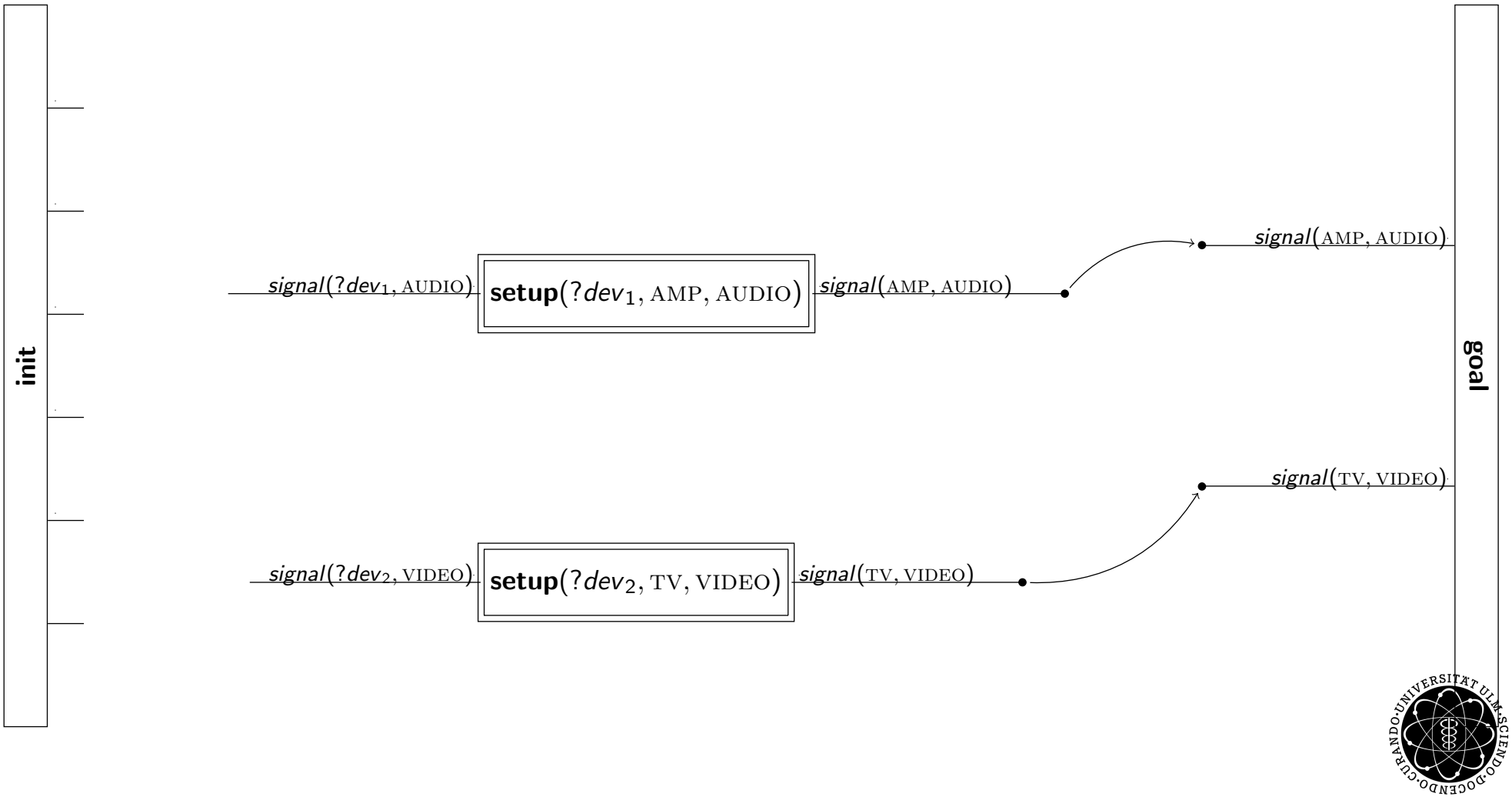


Why bother about plan linearization?

- planning systems return plans that induce executable sequences of primitive tasks
- plans are executed by a human user
- planning problem and solution include information that can be exploited
- we give three domain-independent approaches and illustrate them in the “home theater” example domain

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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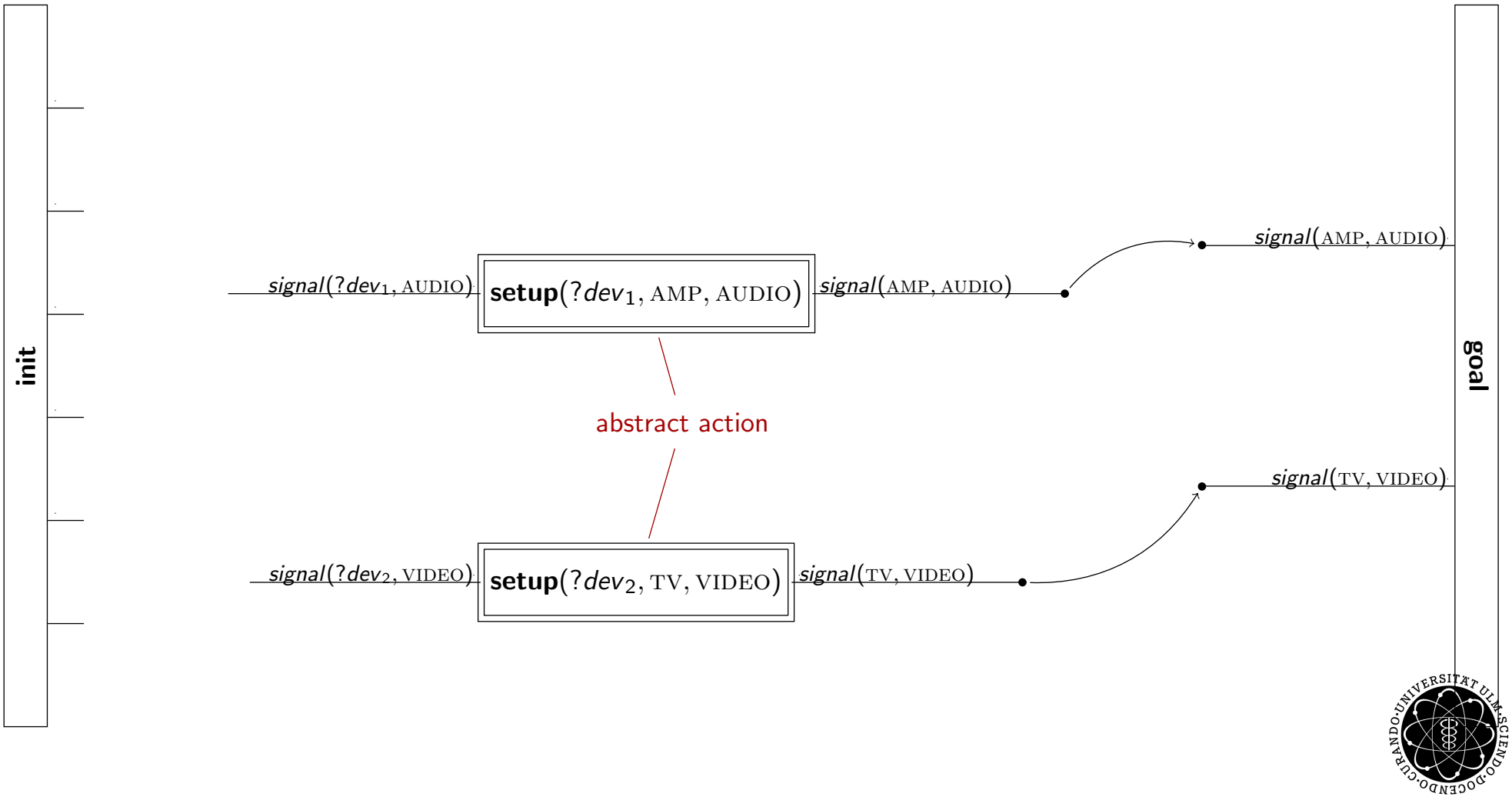
goal
signal(?dev1, AUDIO)
setup(?dev1, AMP, AUDIO)
signal(AMP, AUDIO)
signal(AMP, AUDIO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
signal(TV, VIDEO)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setup(?dev1, AMP, AUDIO)
signal(AMP, AUDIO)
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abstract action
signal(?dev2, VIDEO)
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signal(TV, VIDEO)
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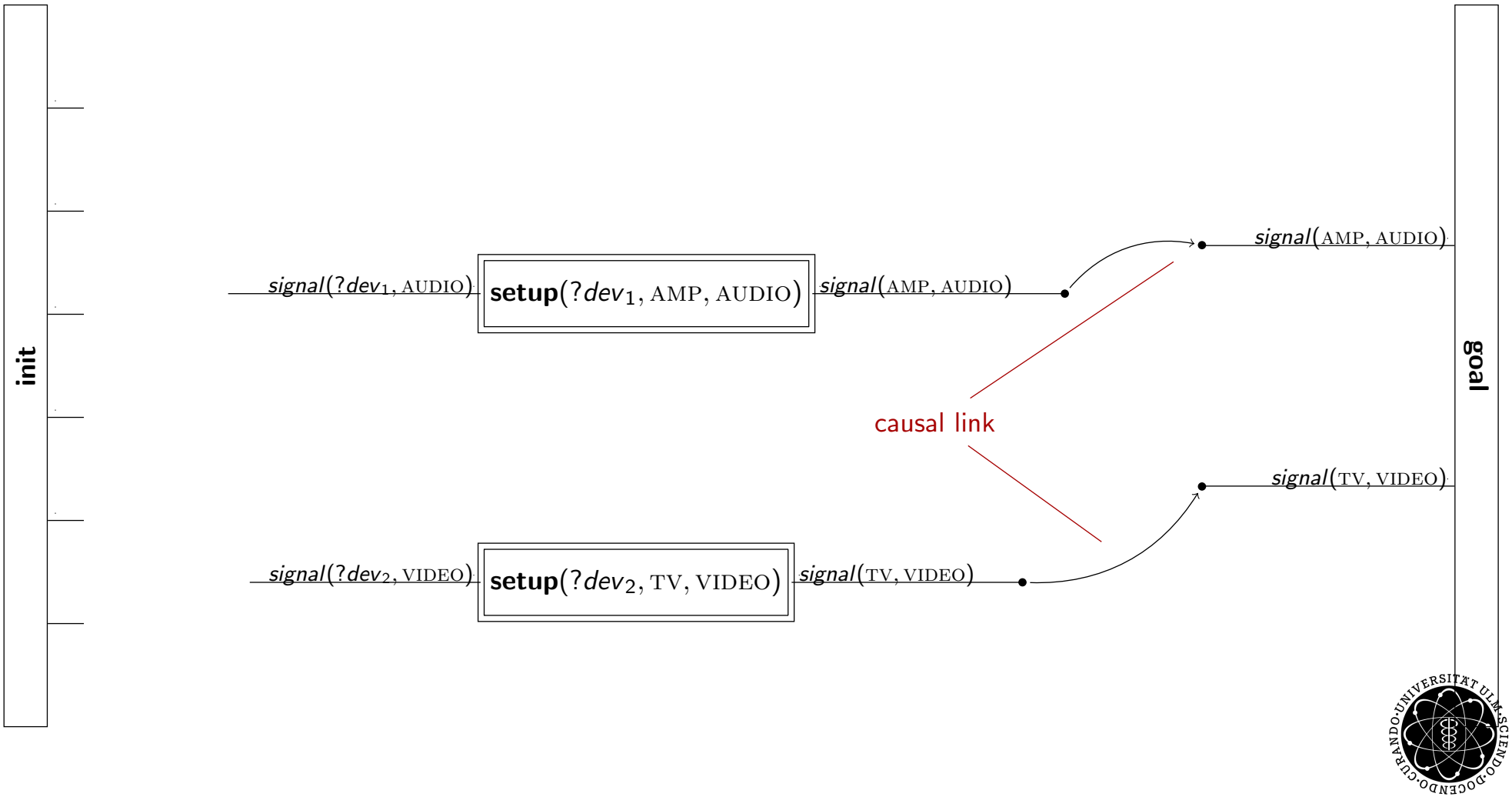
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goal
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setup(?dev1, AMP, AUDIO)
signal(AMP, AUDIO)
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causal link
signal(?dev2, VIDEO)
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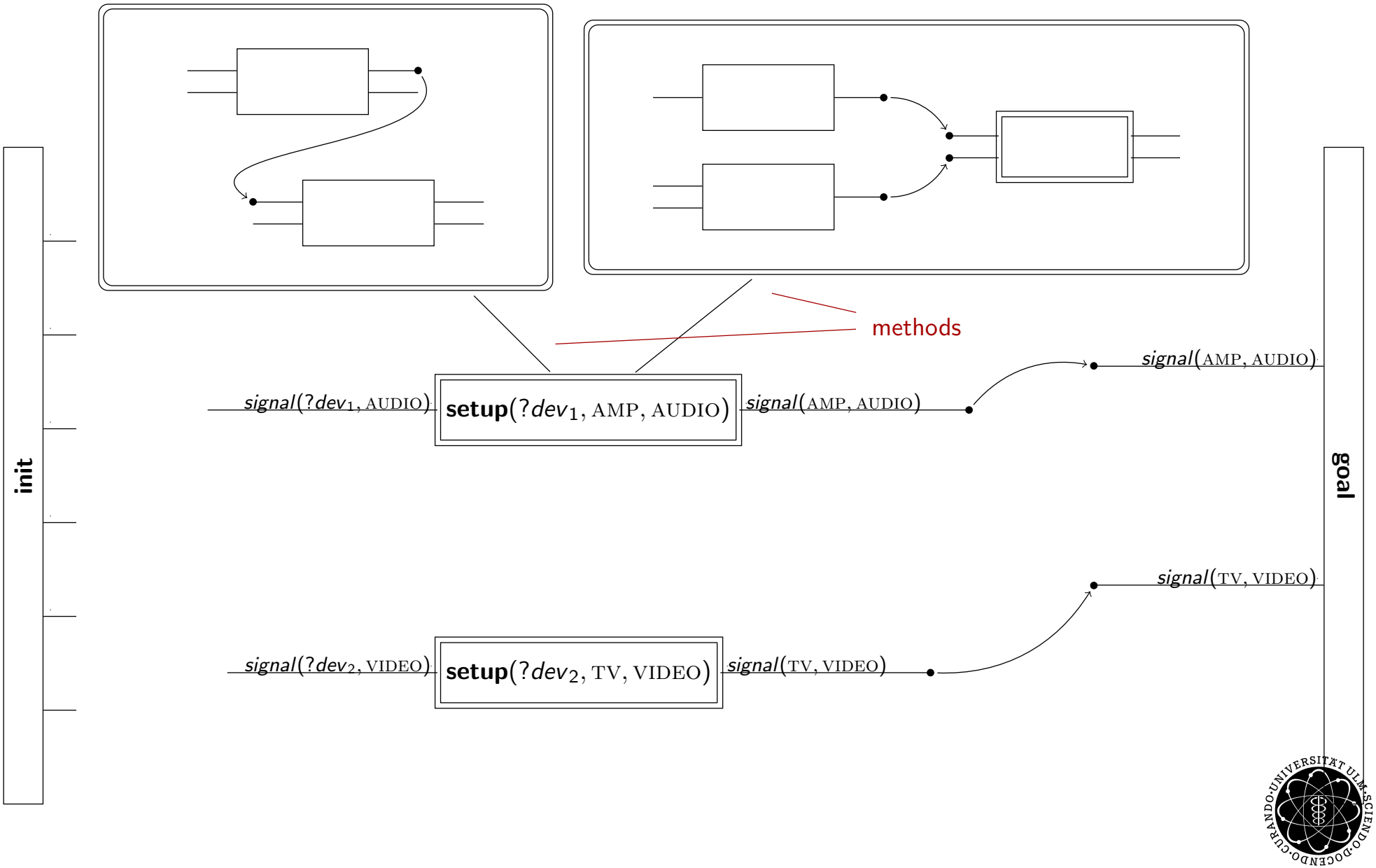
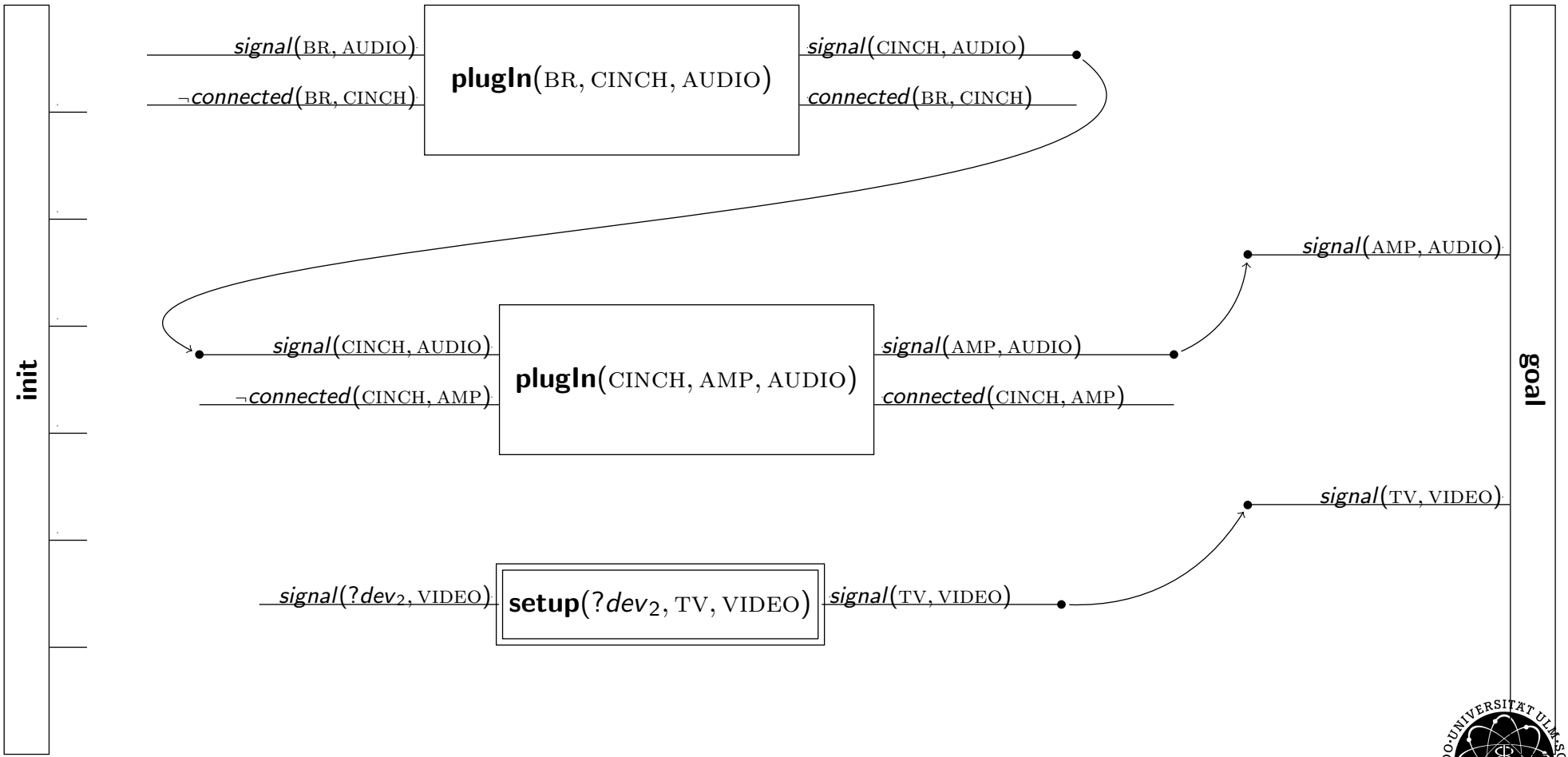
signal(TV, VIDEO)
signal(TV, VIDEO)


methods
init
goal
signal(?dev1, AUDIO)
setup(?dev1, AMP, AUDIO)
signal(AMP, AUDIO)
signal(AMP, AUDIO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
signal(TV, VIDEO)


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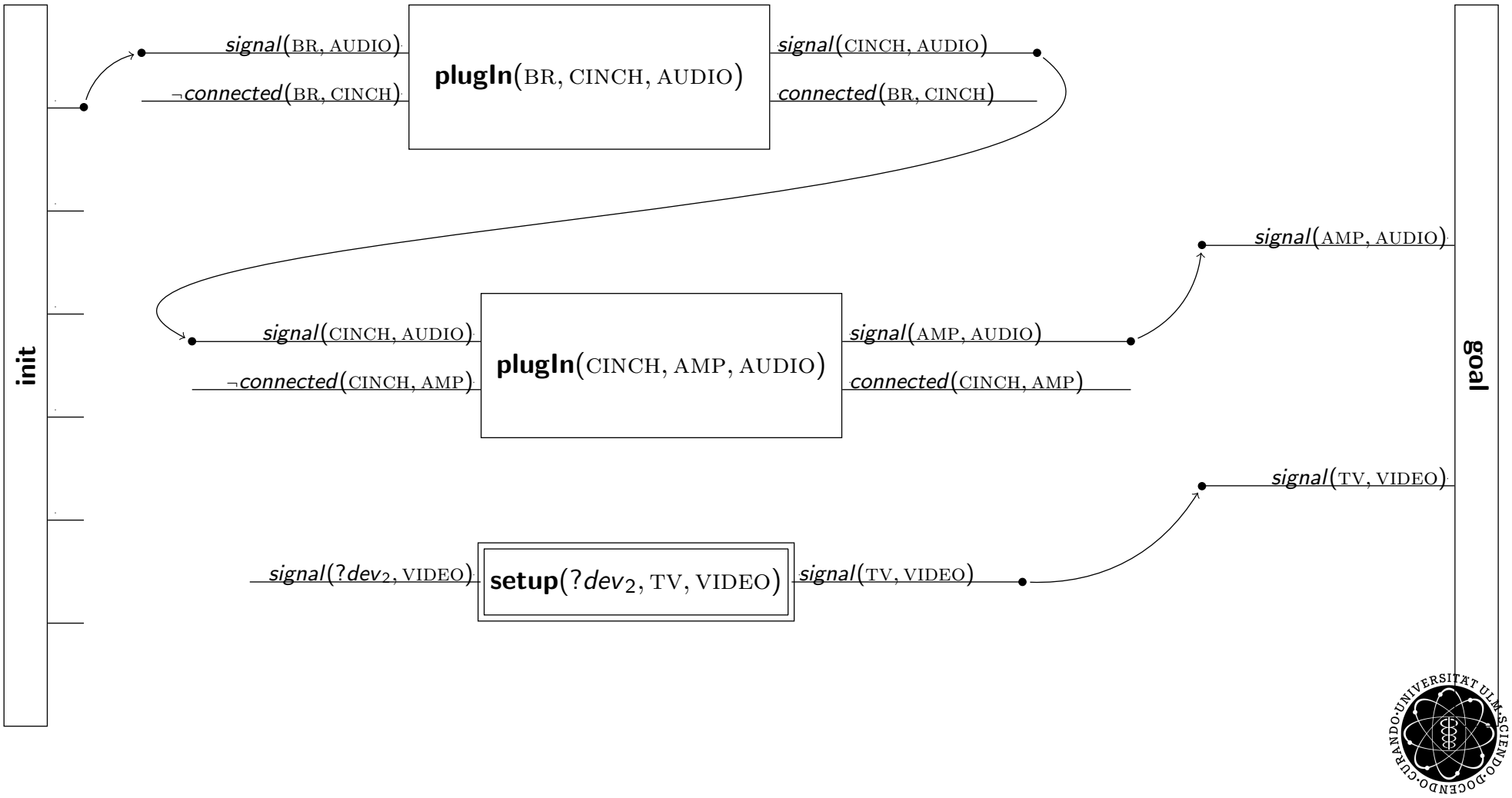
plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AMP, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AMP)
plugIn(CINCH, AMP, AUDIO)
signal(AMP, AUDIO)
connected(CINCH, AMP)
signal(TV, VIDEO)
signal(?dev2, VIDEO)
setup(?dev2, TV, VIDEO)
signal(TV, VIDEO)
goal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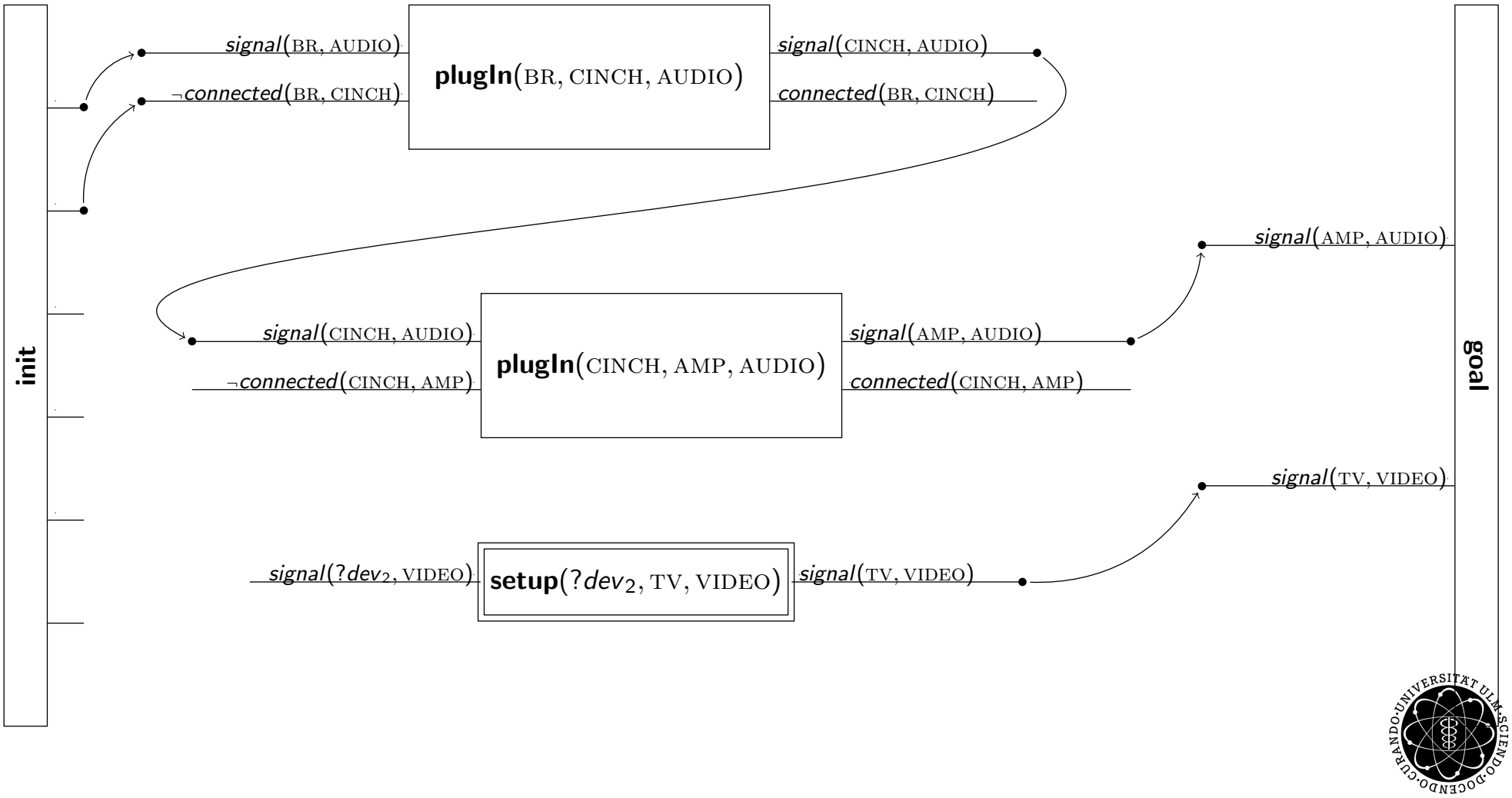
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plugIn(CINCH, AMP, AUDIO)
signal(AMP, AUDIO)
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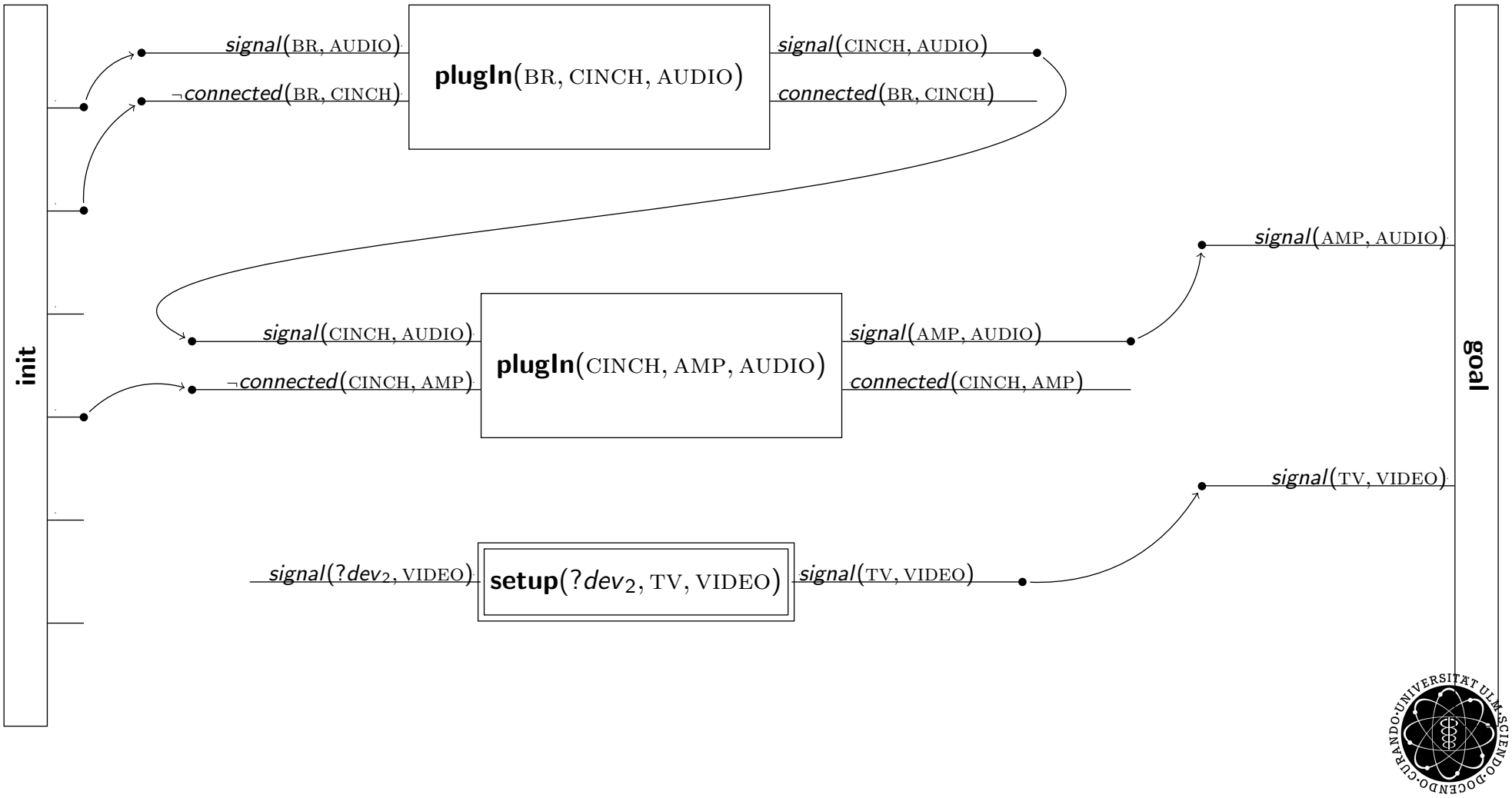
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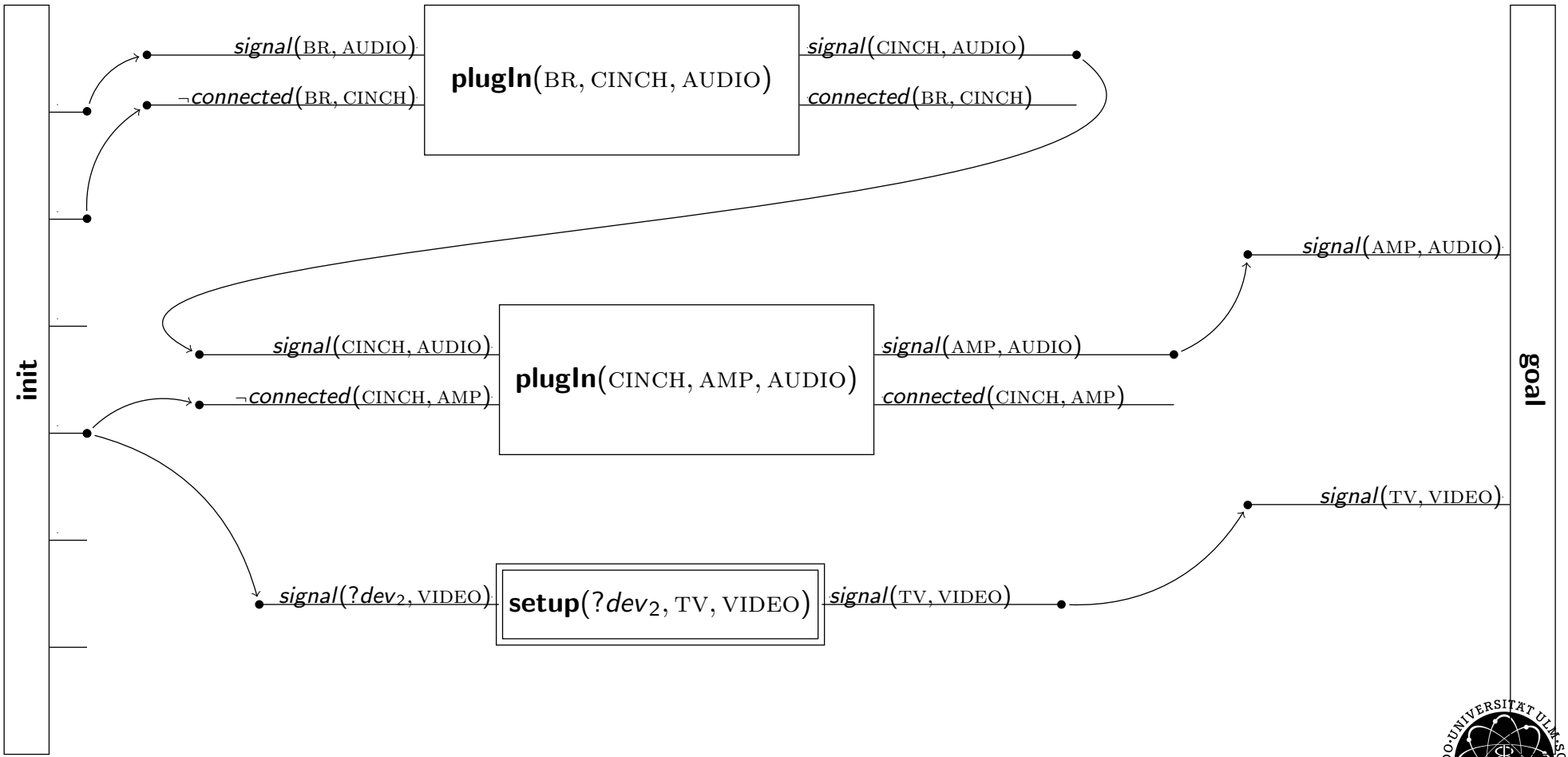
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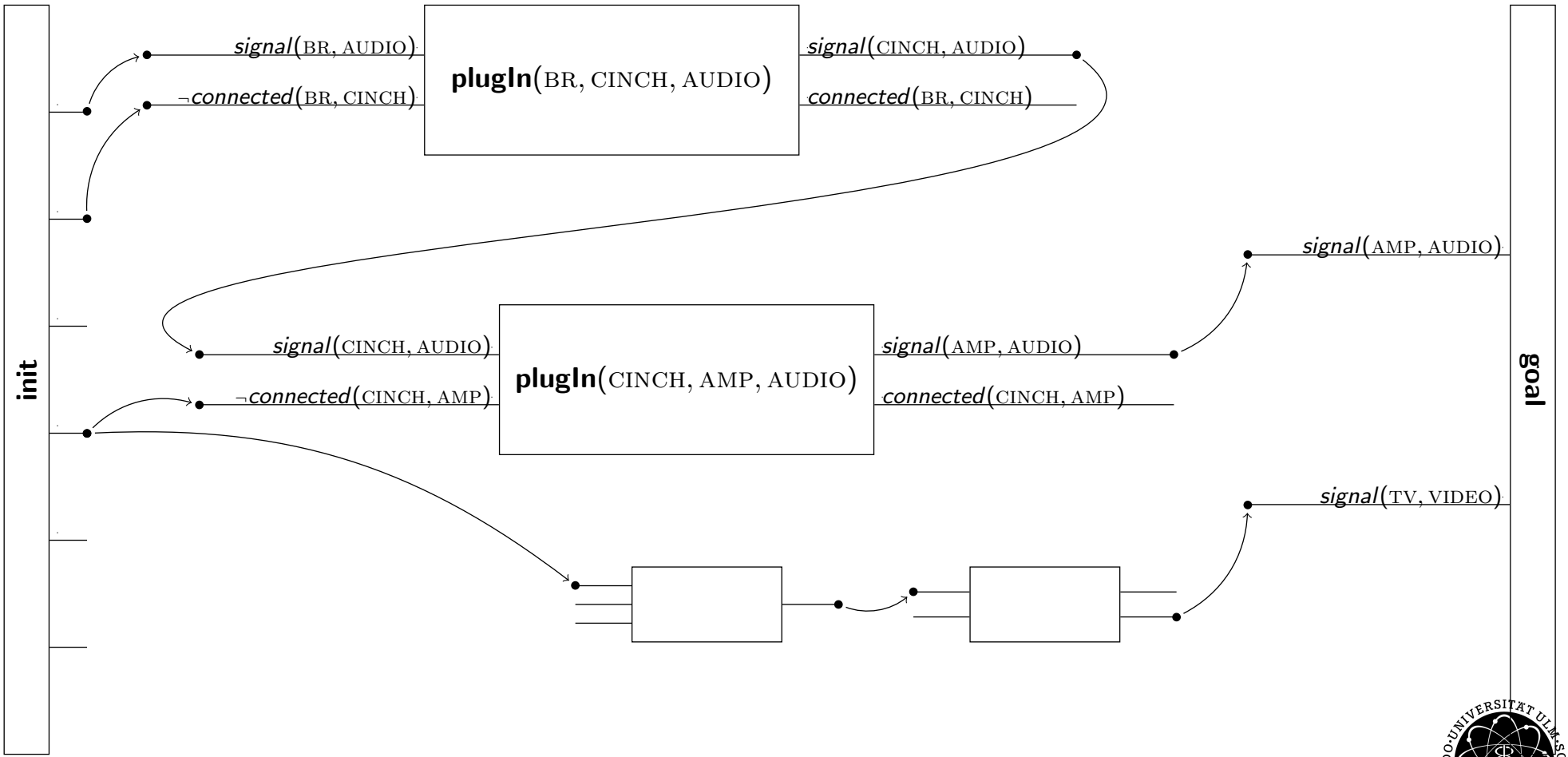
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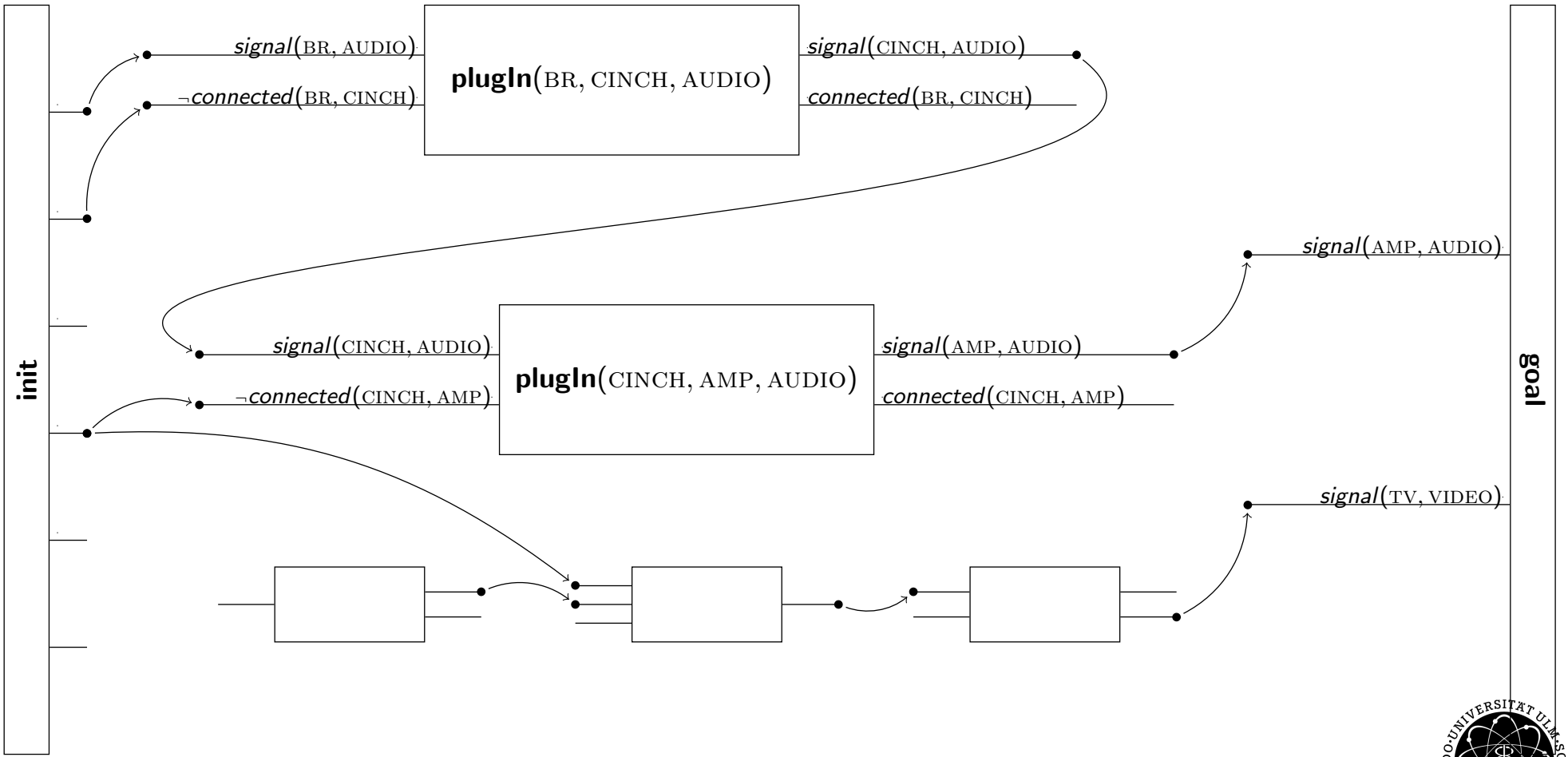
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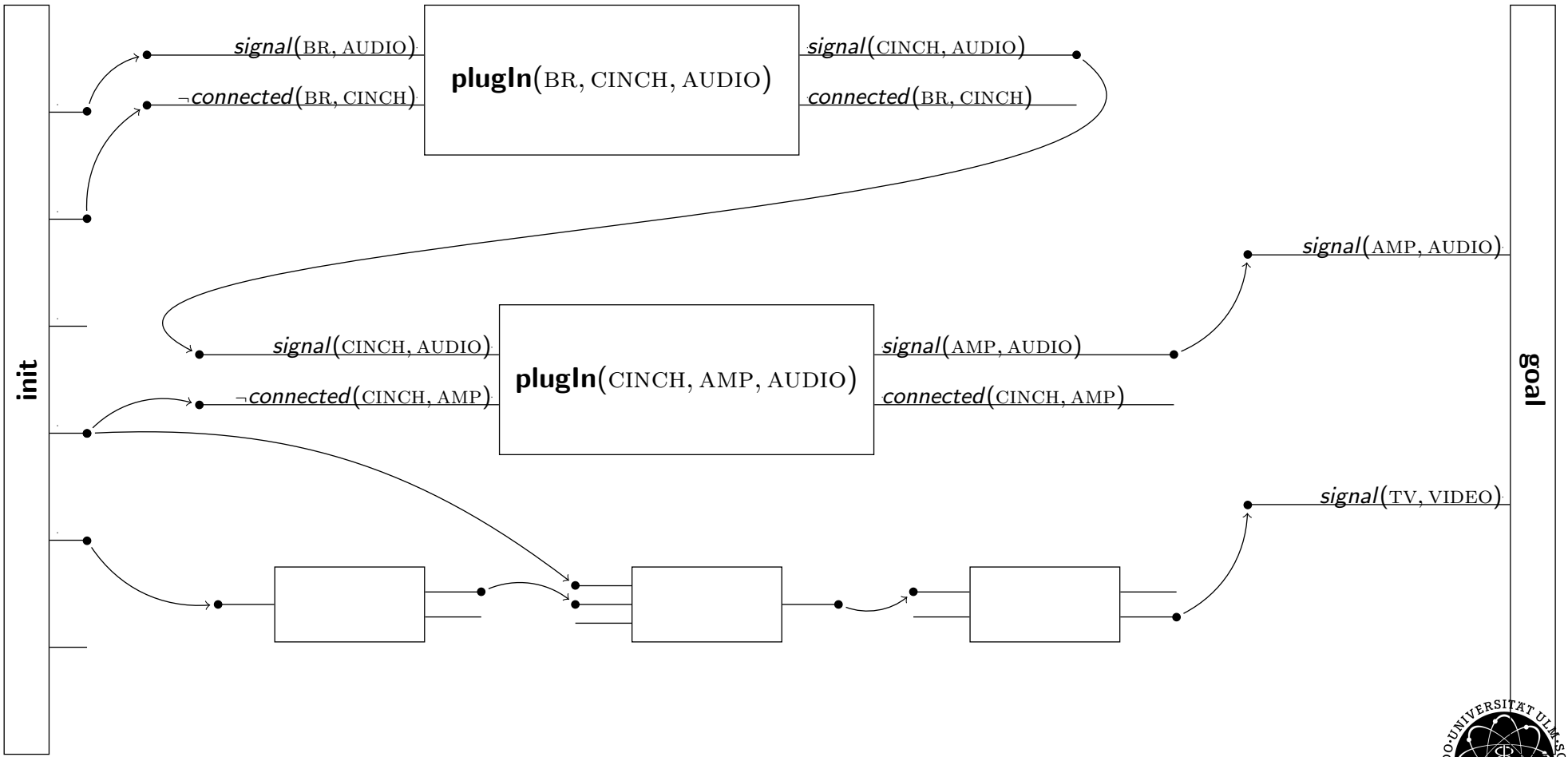
connected(CINCH, AMP)
signal(TV, VIDEO)
goal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connected(BR, CINCH)
signal(AMP, AUDIO)
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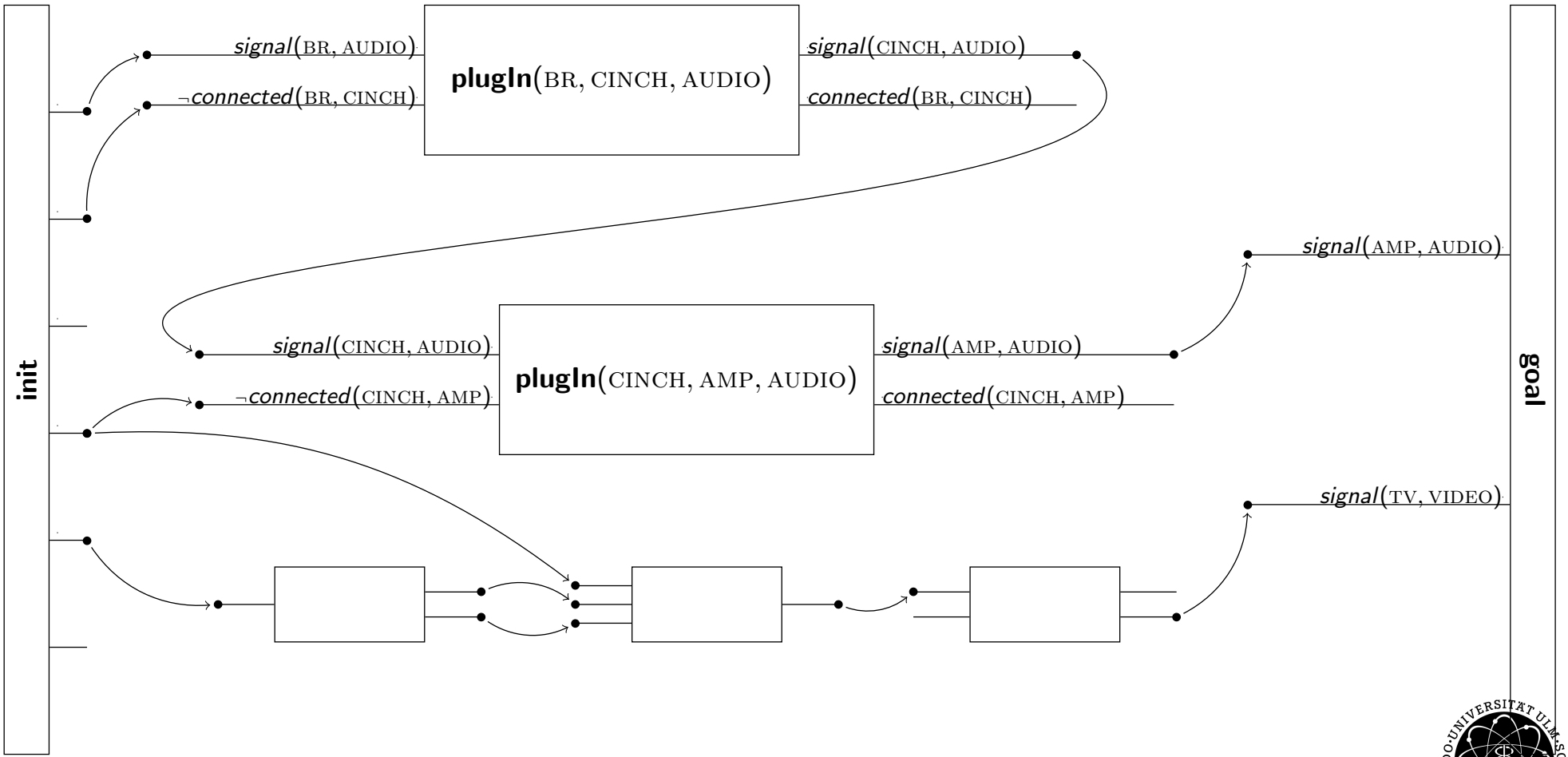
signal(AMP, AUDIO)
connected(CINCH, AMP)
signal(TV, VIDEO)
goal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plugIn(BR, CINCH, AUDIO)
signal(CINCH, AUDIO)
connected(BR, CINCH)
signal(AMP, AUDIO)
signal(CINCH, AUDIO)
¬connected(CINCH, AMP)
plugIn(CINCH, AMP, AUDIO)
signal(AMP, AUDIO)
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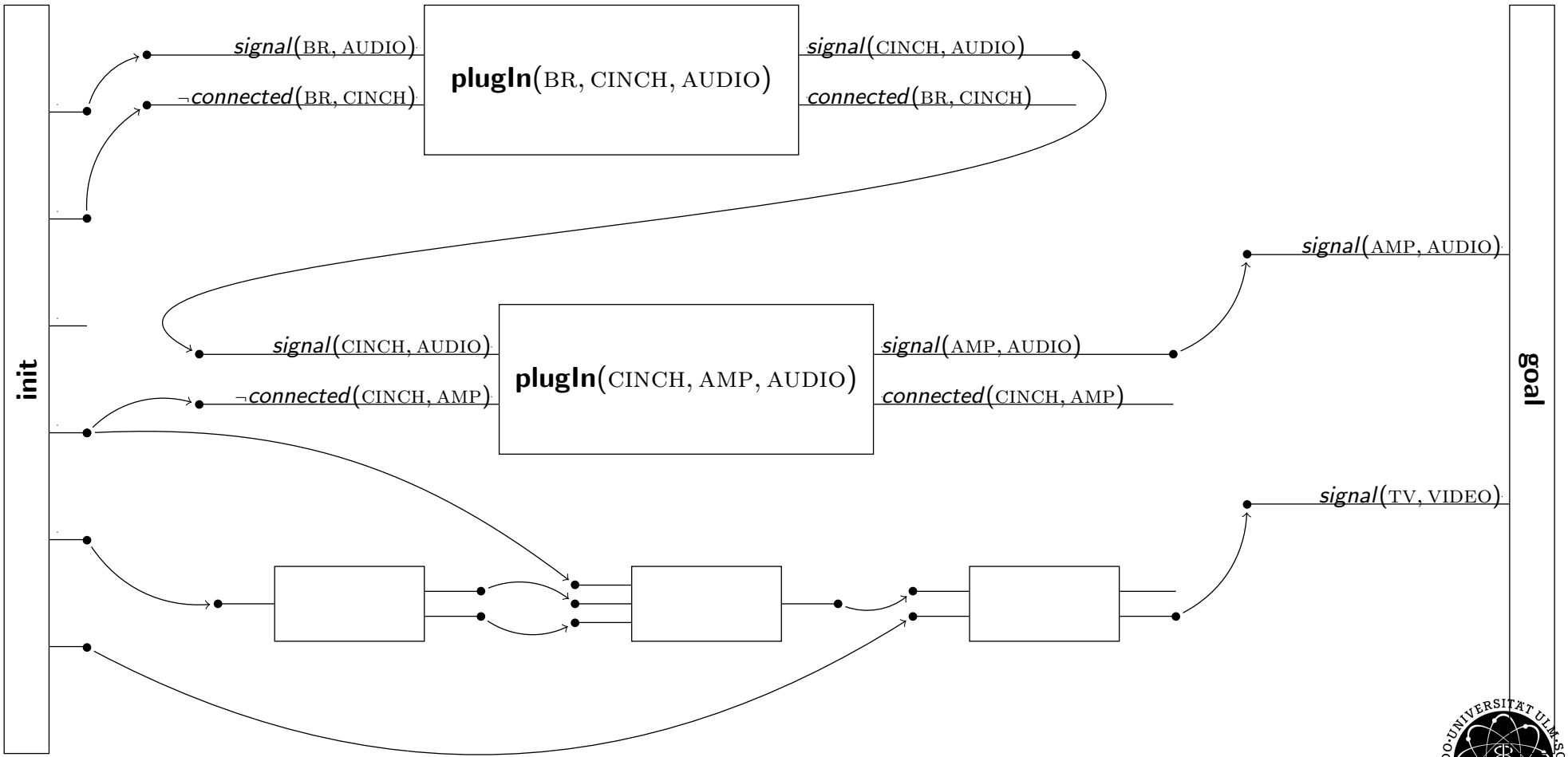
signal(TV, VIDEO)
goal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connected(BR, CINCH)
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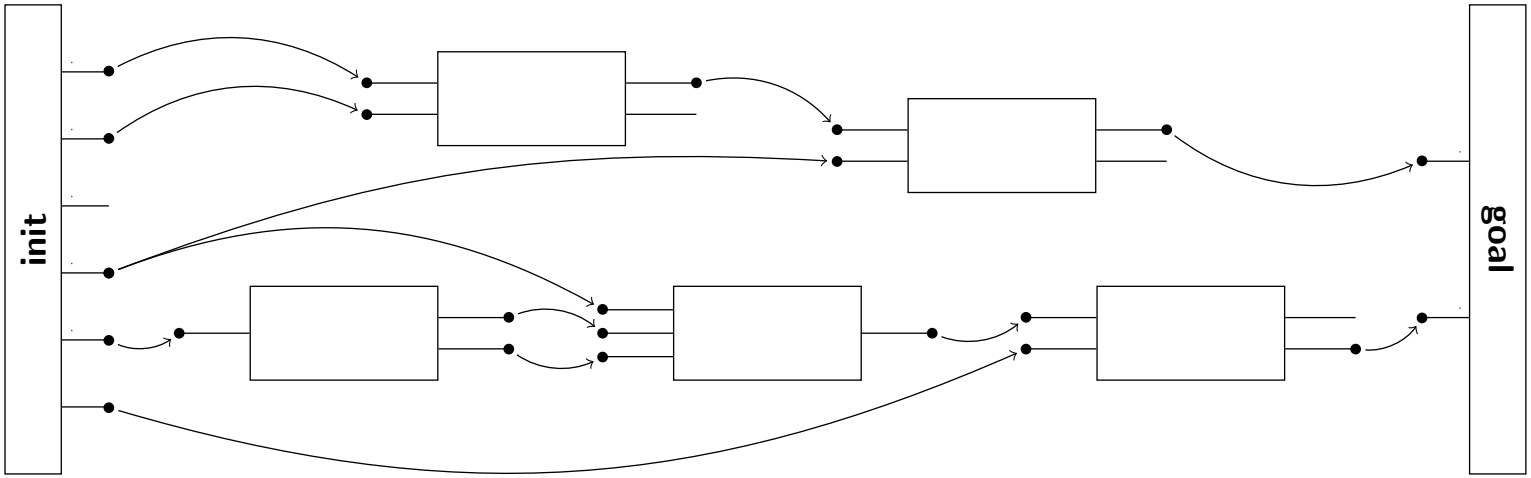
signal(AMP, AUDIO)
connected(CINCH, AMP)
signal(TV, VIDEO)
goal

generate a plausible linearization of the actions:



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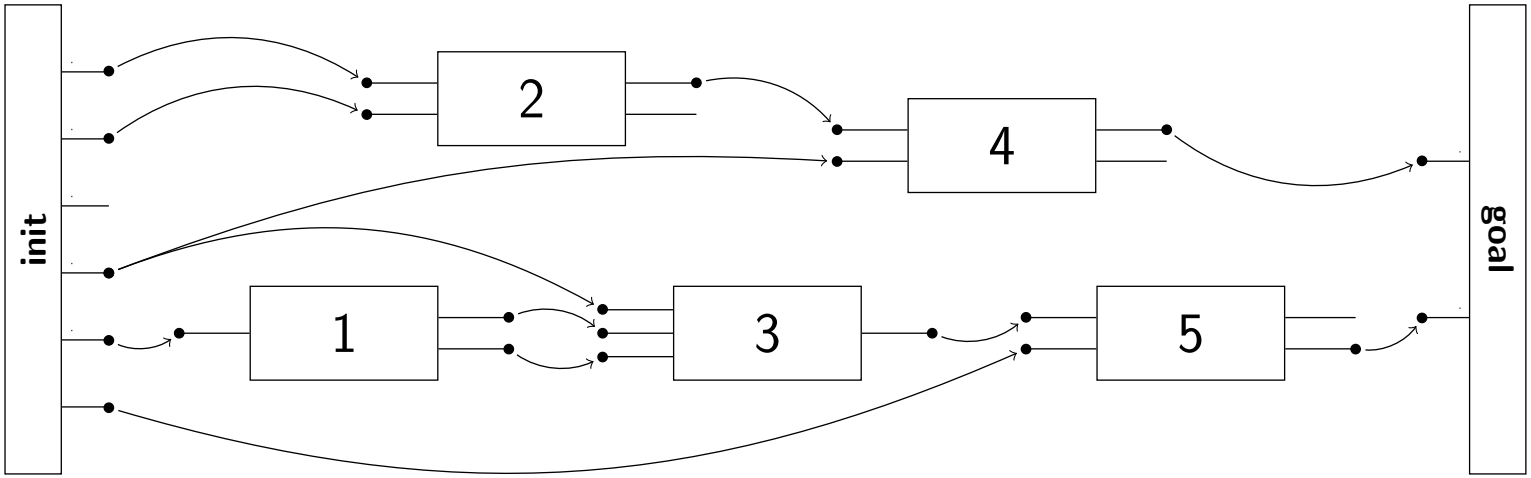
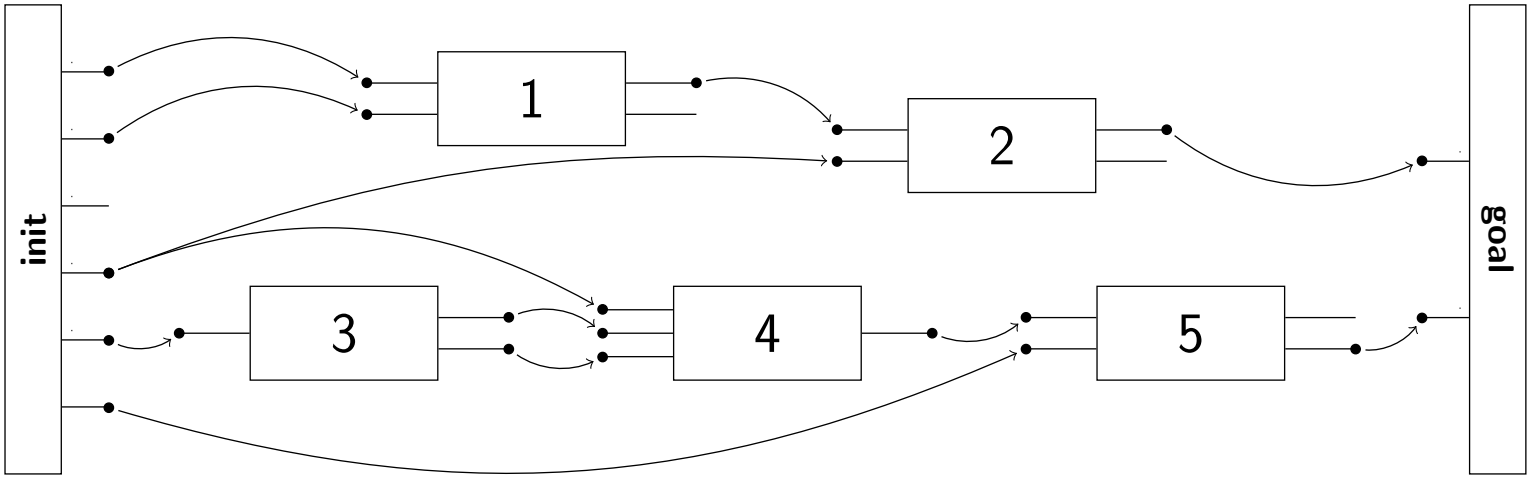


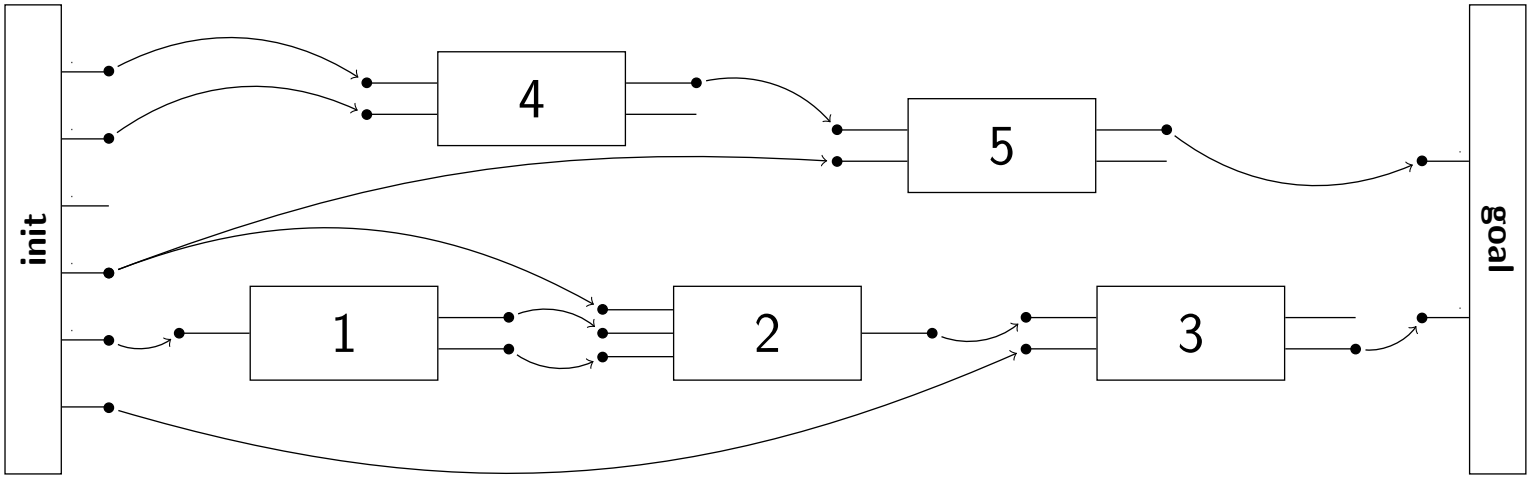
1: connect ...
2: connect CINCH cable (the first end) with Blu-ray player
3: connect ...
4: connect CINCH cable (the other end) with AV receiver
5: connect ...

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 ...

generate a plausible linearization of the actions:



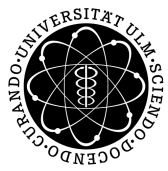
1: connect ...
2: connect ...
3: connect ...
4: connect CINCH cable (the first end) with Blu-ray player
5: connect CINCH cable (the other end) with AV receiver

information used for finding user-friendly plan linearizations:

- the planning domain and
- the solution to the given planning problem

we introduce three domain-independent linearizations approaches based on:

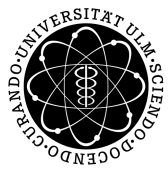
- **action parameters**
- **causal links** in the plan
- **decomposition hierarchy**



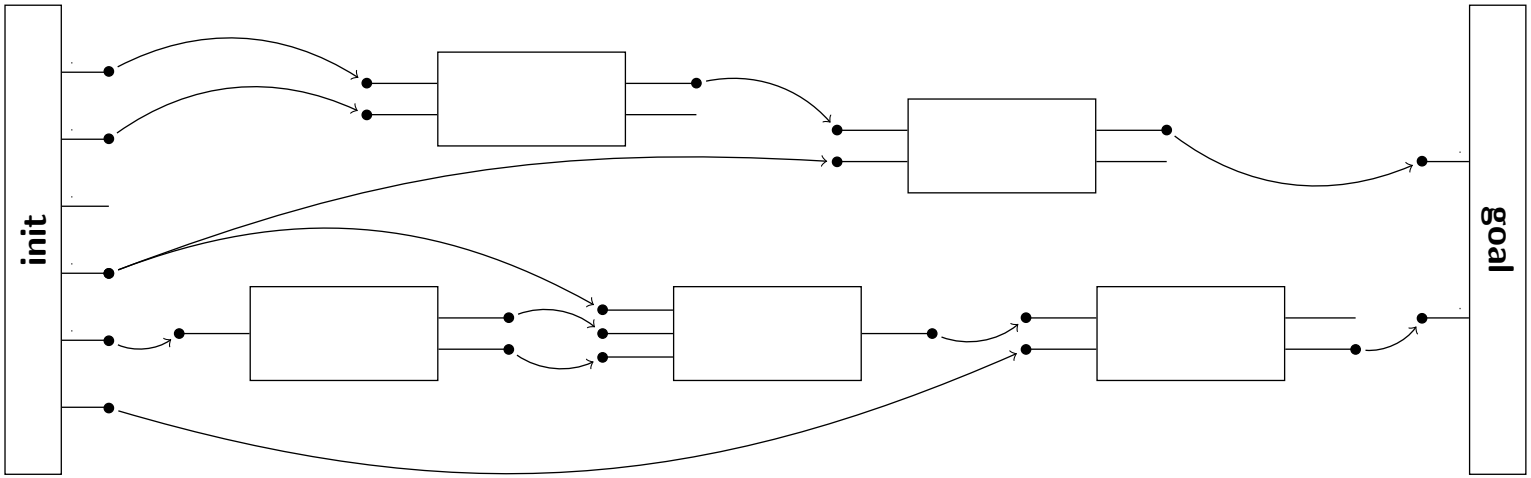
Parameter-based plan linearization

- actions represent activities to do
- parameters introduce the items/objects/subjects to use

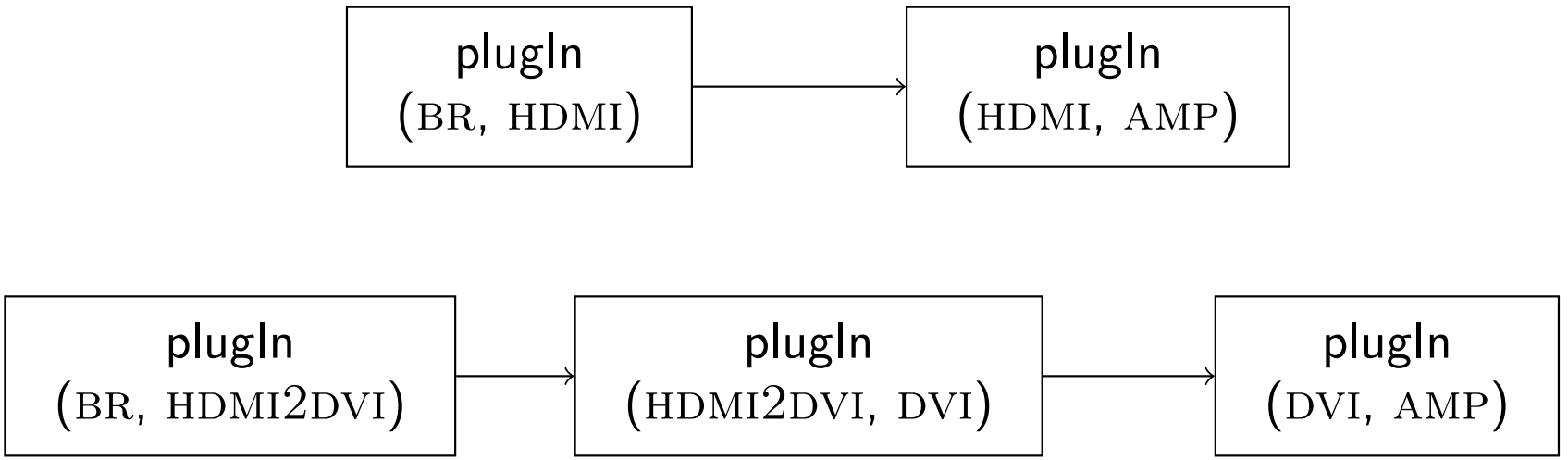
→ execute actions involving the same parameters consecutively



Solution plan (schematically, with causal structure)



Solution plan (ordering constraints, action schemata)



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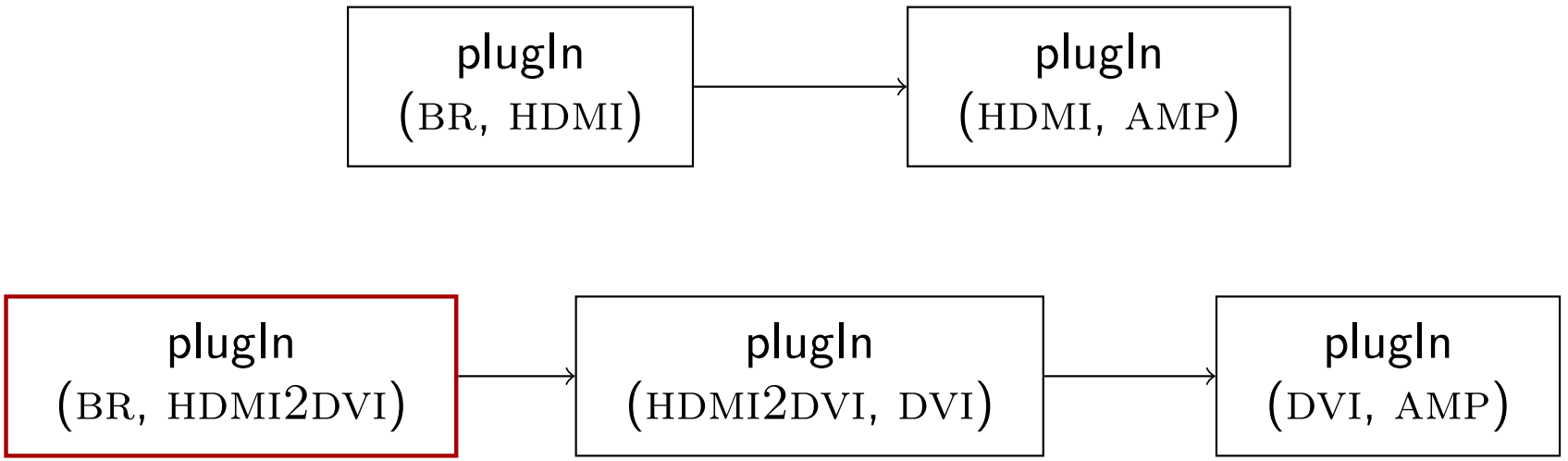
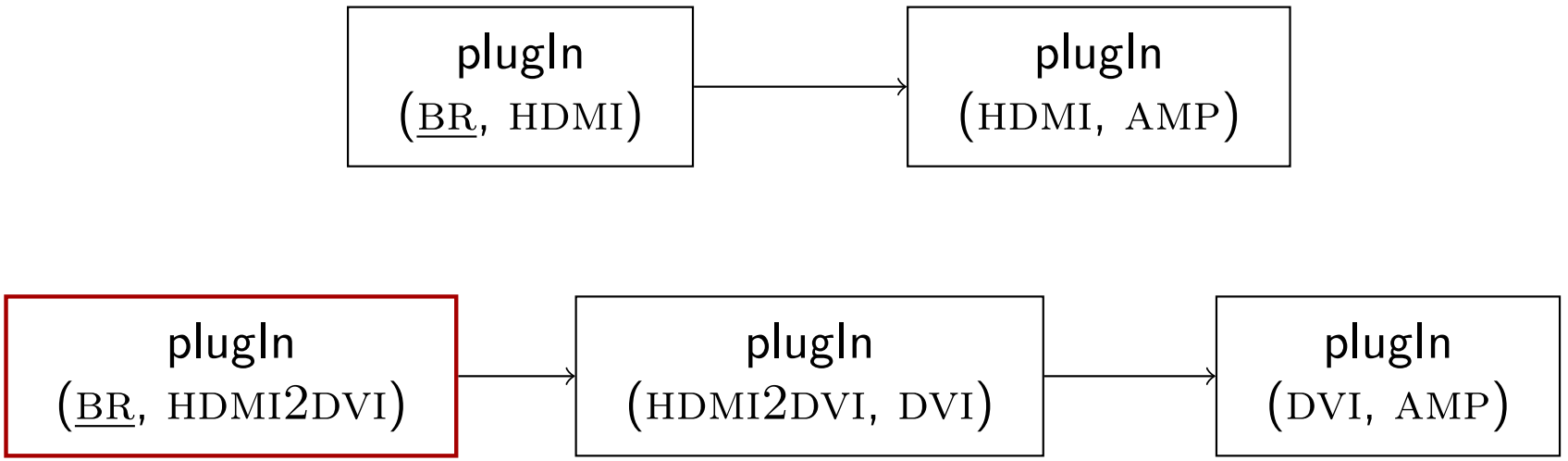


Solution plan (ordering constraints, action schemata)



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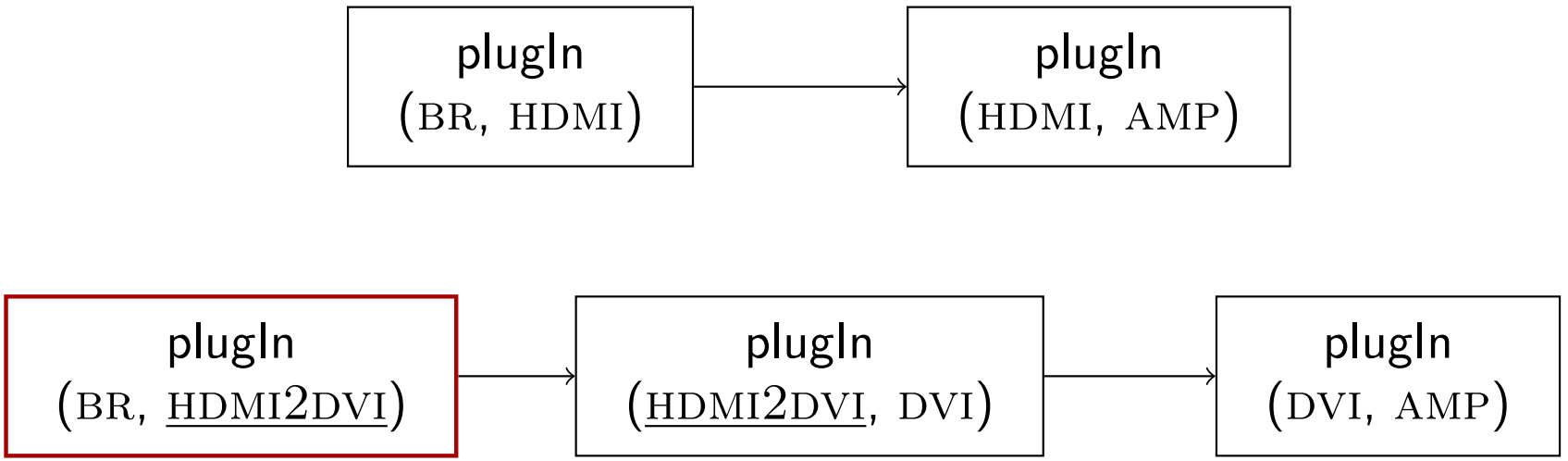
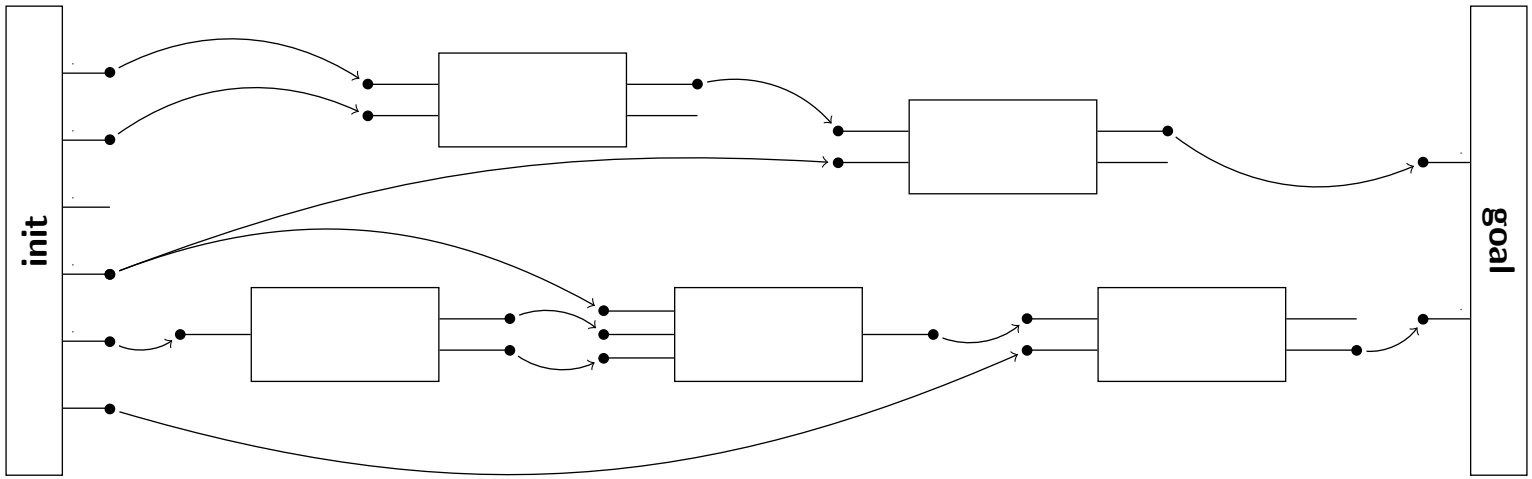


Causal link-based plan linearization

- causal links explicitly represent the causal structure of the plan
- each link was introduced to solve a flaw – all links are required

→ execute connected actions consecutively



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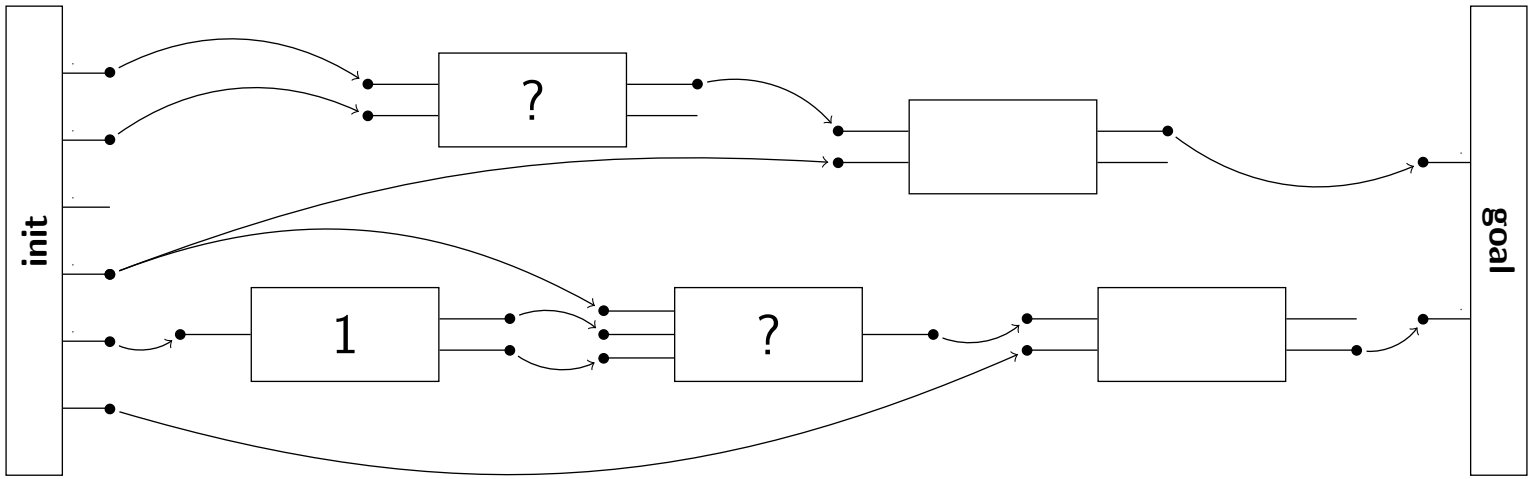

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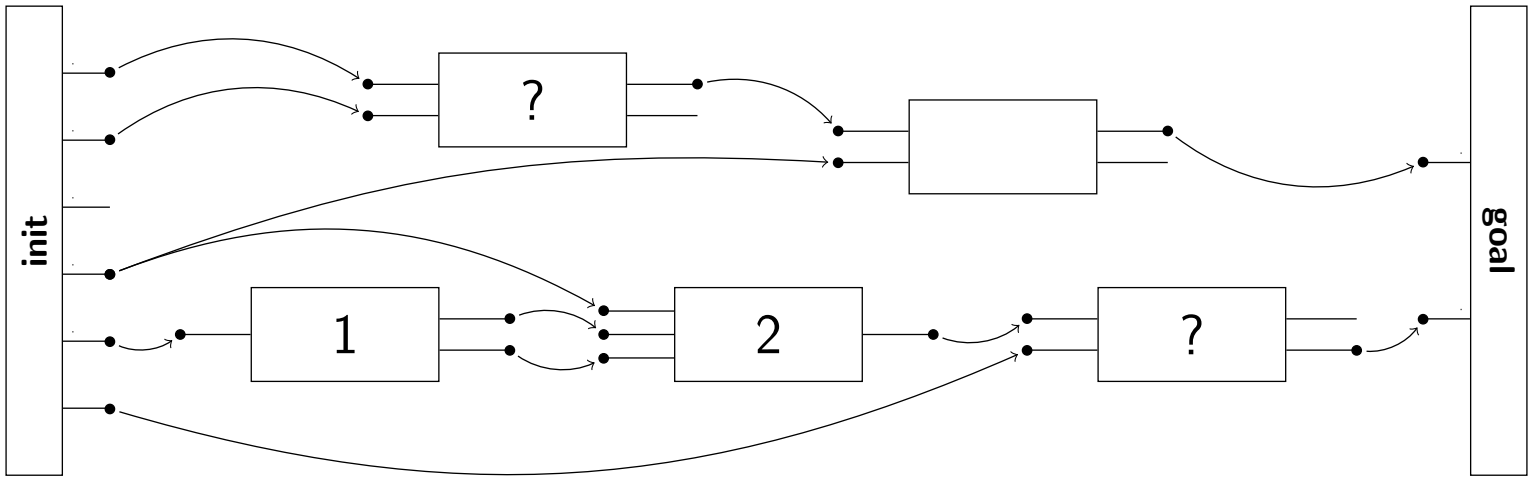

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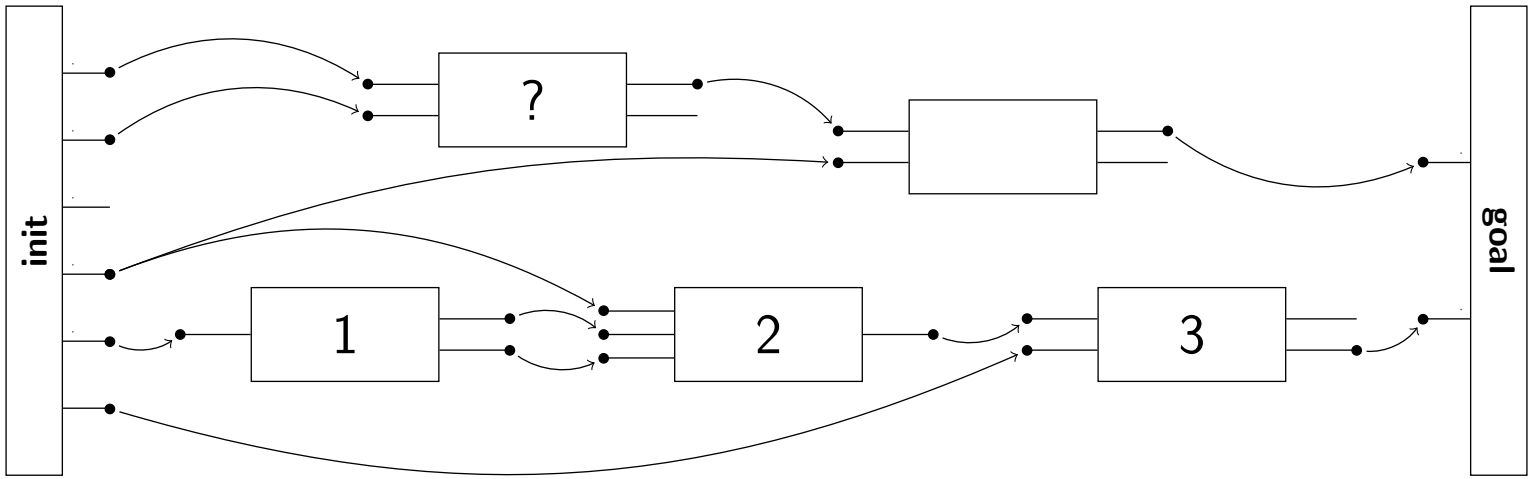

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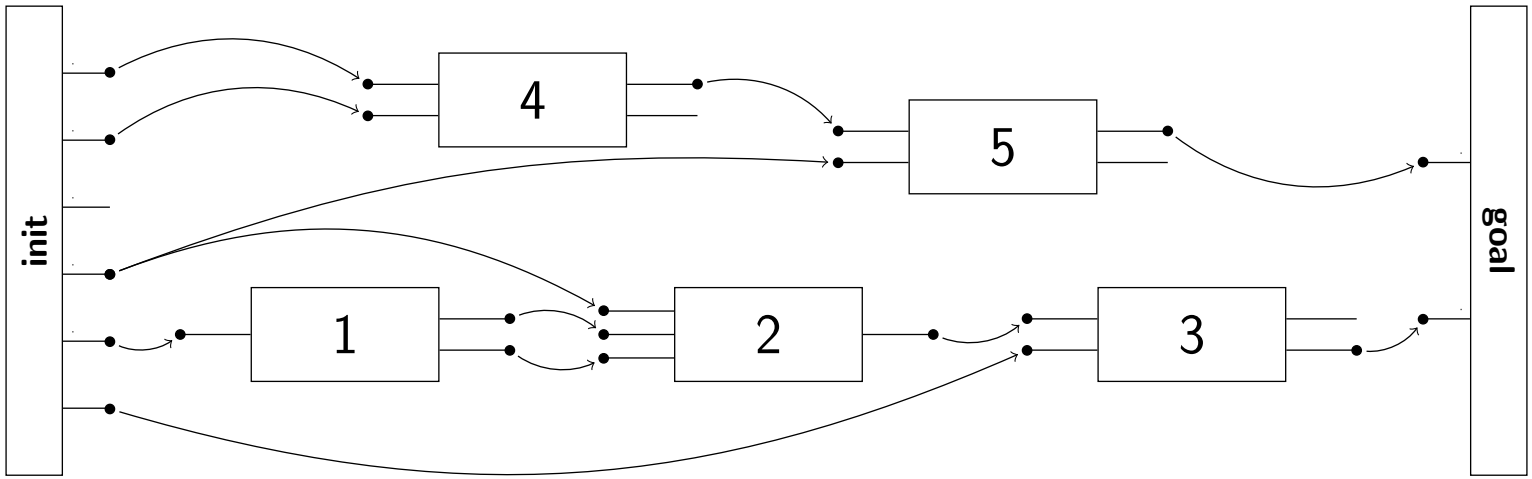
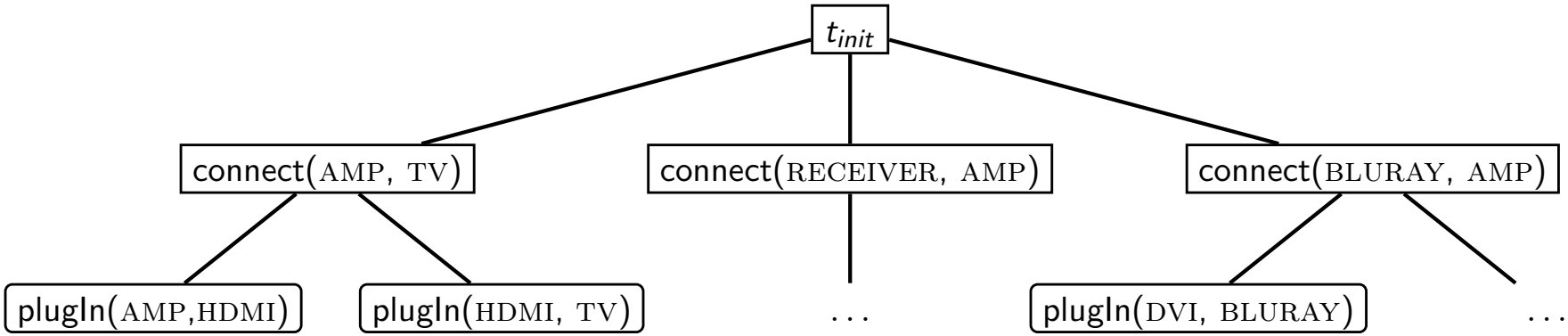
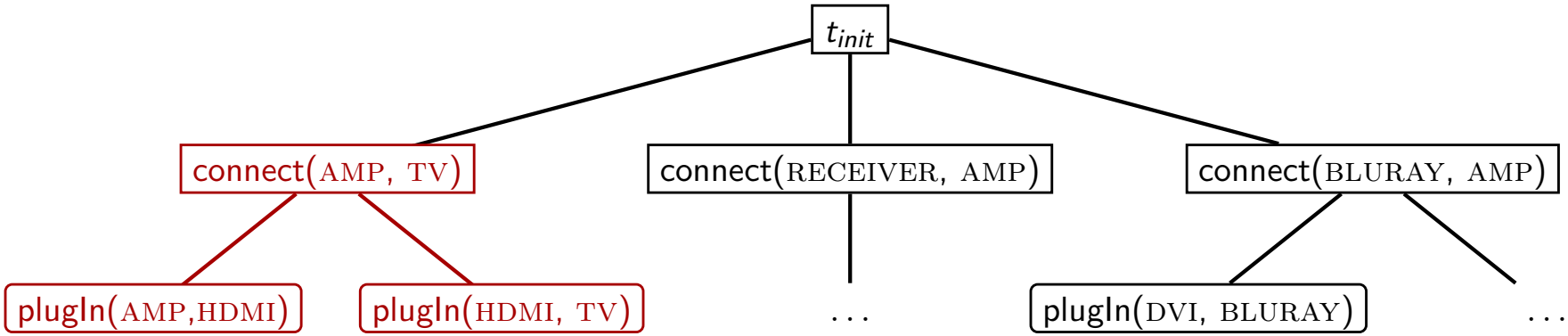


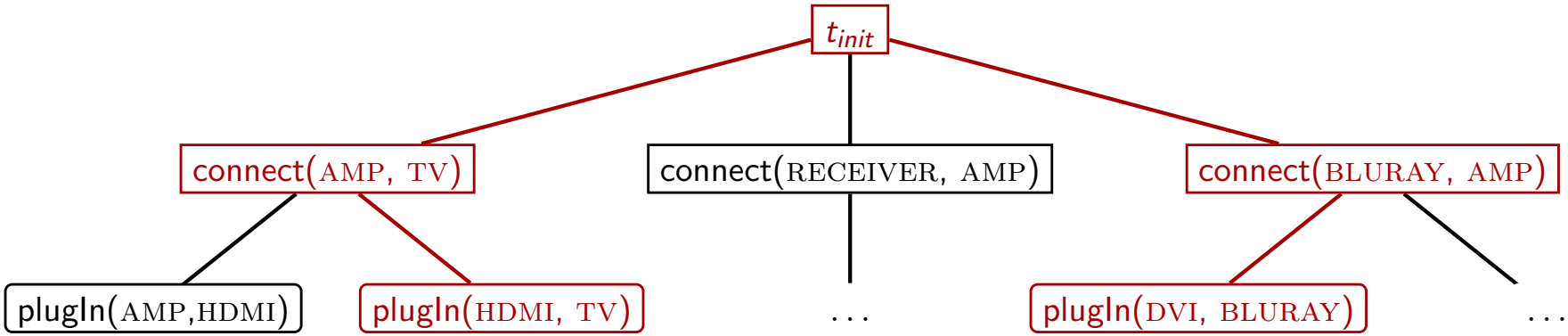
Decomposition-based plan linearization

- domain contains expert knowledge
- tasks that are introduced by the same method implement the same abstract task ($\rightarrow$ semantically related!)
- we generalize this relationship to tasks that are not in the same method ($\rightarrow$ use Task Decomposition Graph (TDG))

$\rightarrow$ execute actions that are close to each other in the TDG consecutively


t_{init}
connect(AMP, TV)
connect(RECEIVER, AMP)
connect(BLURAY, AMP)
plugIn(AMP,HDMI)
plugIn(HDMI, TV)
...
plugIn(DVI, BLURAY)
...


t_{init}
connect(AMP, TV)
connect(RECEIVER, AMP)
connect(BLURAY, AMP)
plugIn(AMP,HDMI)
plugIn(HDMI, TV)
...
plugIn(DVI, BLURAY)
...


t_{init}
connect(AMP, TV)
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plugIn(AMP,HDMI)
plugIn(HDMI, TV)
...
plugIn(DVI, BLURAY)
...

Possibilities for Empirical Evaluation

- the utilities have to be evaluated empirically
- what is the objective?
  - imitating human behavior
  - maximize subjective appraisal of humans executing a plan
  - optimize some objective (measurable) metric

Summary

- plan linearization is required if we plan for human users
- we gave three domain-independent utility functions that may help to find reasonable linearizations
- illustrated it in the “home theater” example domain
- all given utilities depend on the planning model
- causal link-based linearization additionally depends on the planning process
- outlined possible objectives and ways to evaluate the different utilities