A First-Order Formalization of Commitments and Goals for Planning

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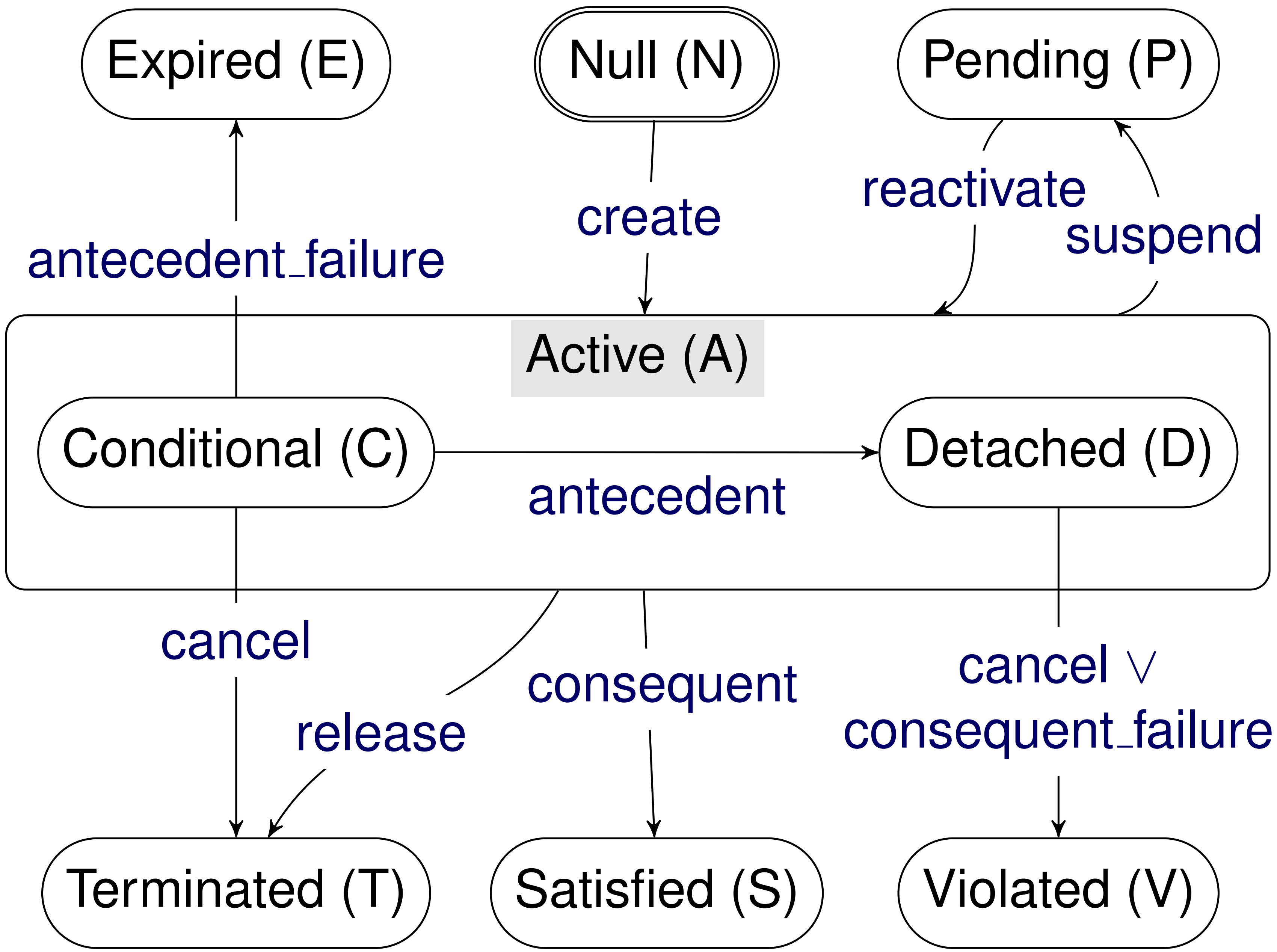
Motivation

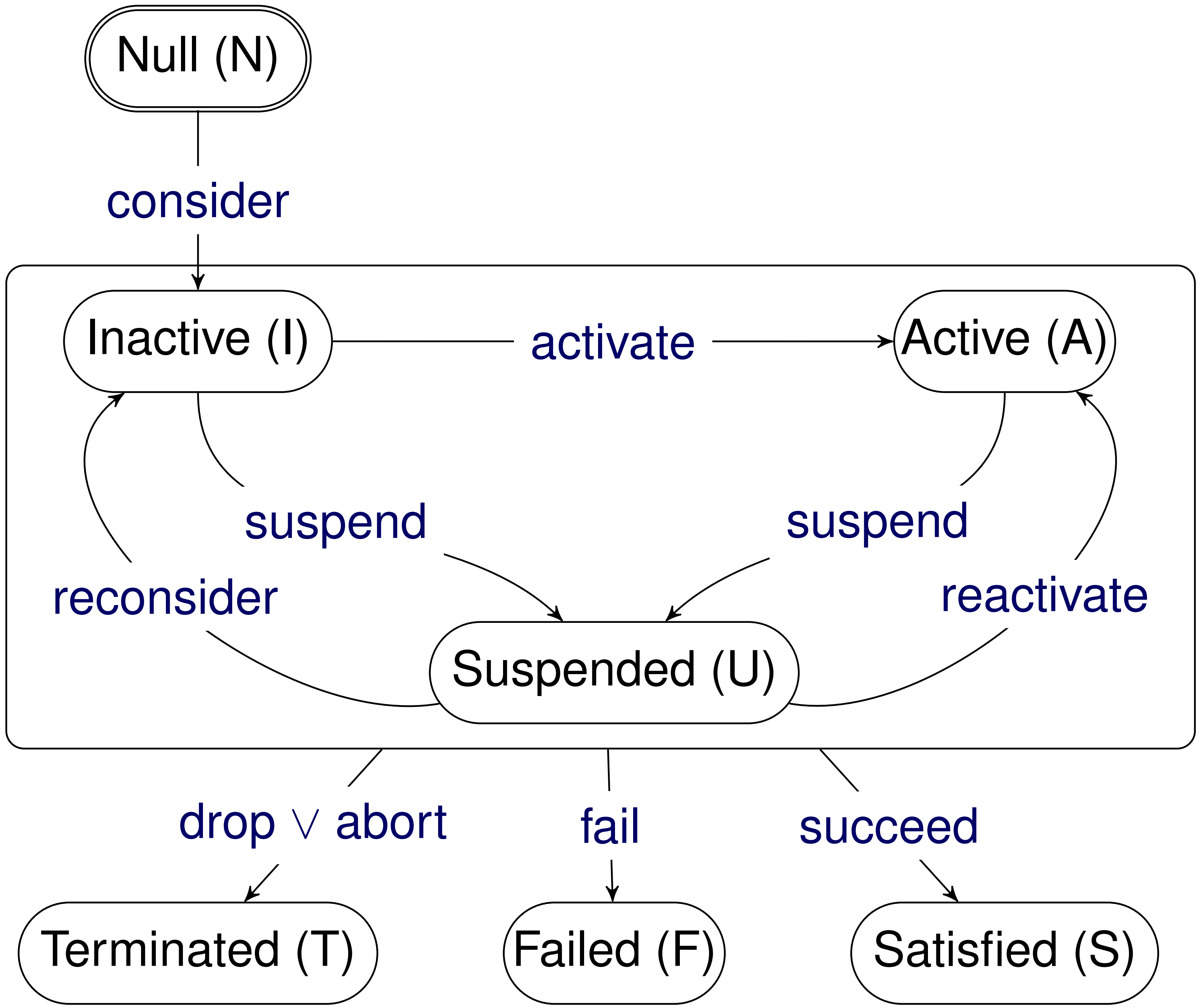
- Commitments have been extensively studied in MAS
  - Encode high-level social relations between agents
  - Define communication protocols among agents
- Previous formalizations
  - Operational semantics for goals and commitments, and their interaction
  - Propositional planning formalization

Commitment Lifecycle



- Formally
  C(Debtor,
  Creditor,
  antecedent,
  consequent)
- E.g.
  C(buyer,seller,goods,paid)

Goal Lifecycle



- Formally
  G(Agent, pg, s, f)
- E.g.
  G(buyer, needsgoods,goods,deadline
)

Relating Commitments and Goals

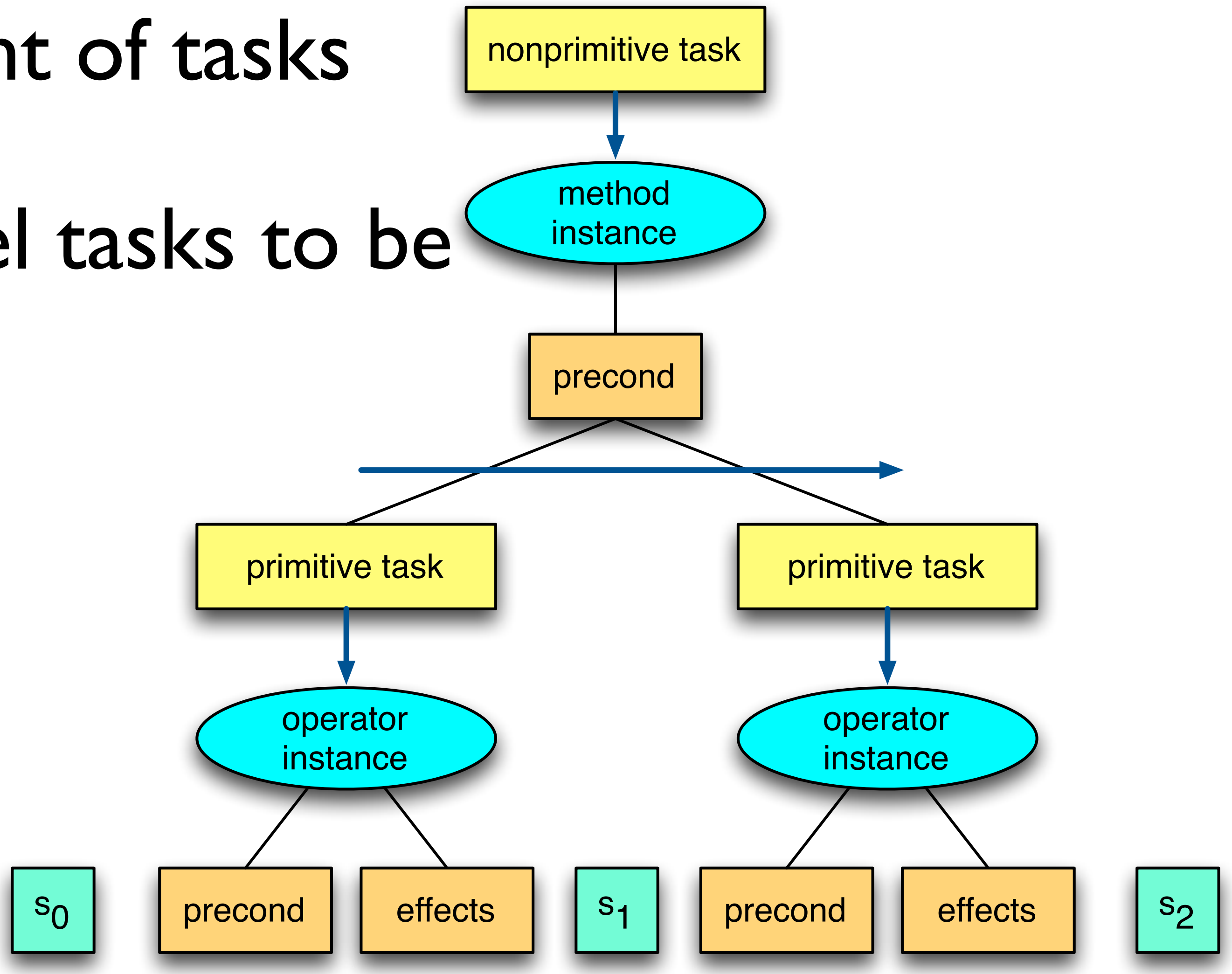
- Practical Rules relating commitments and goals
  - Let G = G(buyer,$\top$,goods,$\bot$)
    and C = C (buyer, seller, goods, pay)
  - **Entice Rule**: If G is active and C is null, buyer creates C

$$\frac{\langle G^A, C^N \rangle}{create(C)}$$

  - Motivation: *Buyer* can achieve its goals of goods by creating the commitment to pay for them to *Seller*

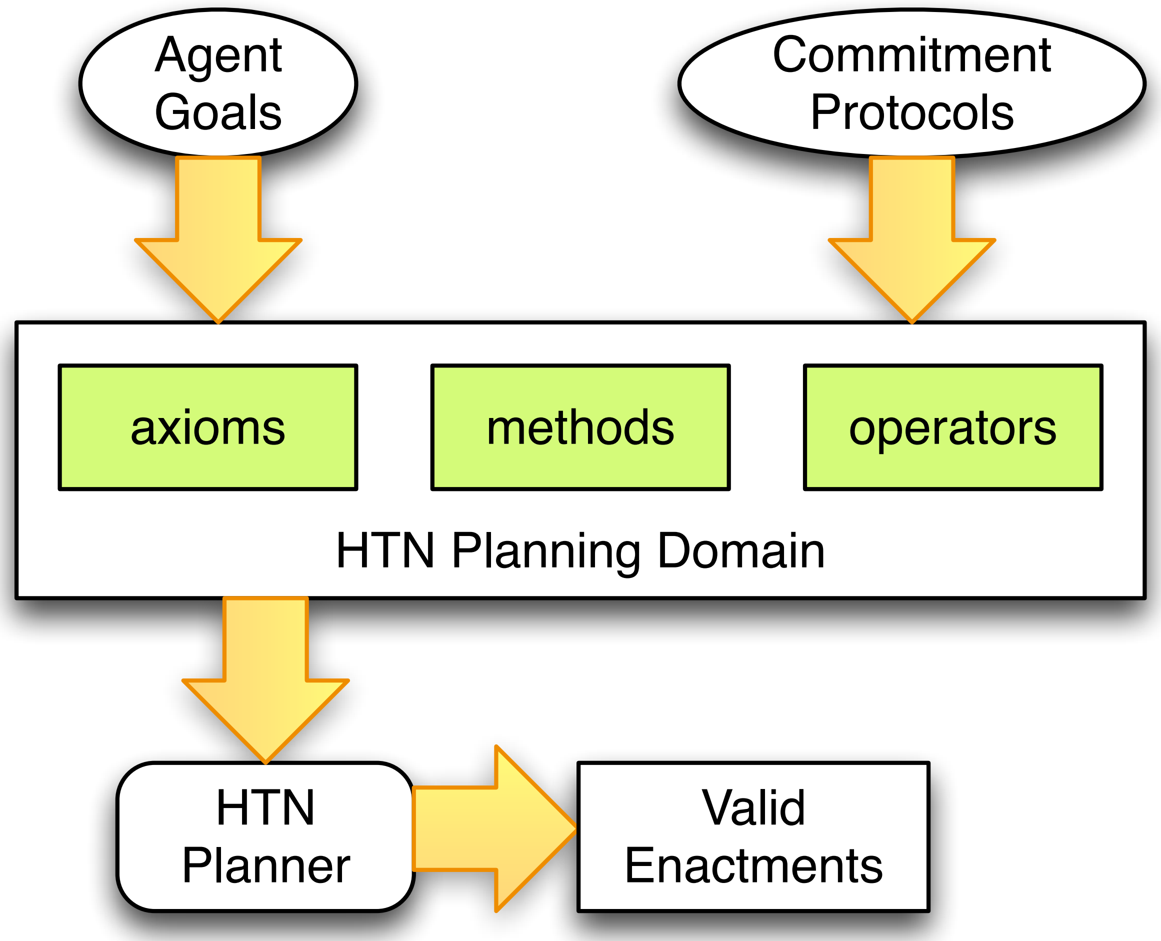
Hierarchical Task Network Planning

- Generates a plan by successive refinement of tasks
  - Non-primitive Tasks - abstract, high-level tasks to be decomposed
  - Primitive Tasks - cannot be further decomposed (operators)
- Multiple implementations (e.g. JSHOP2, SHOP2)
- Abstraction of choice for agent programming languages



HTN Planning for Commitments and Goals

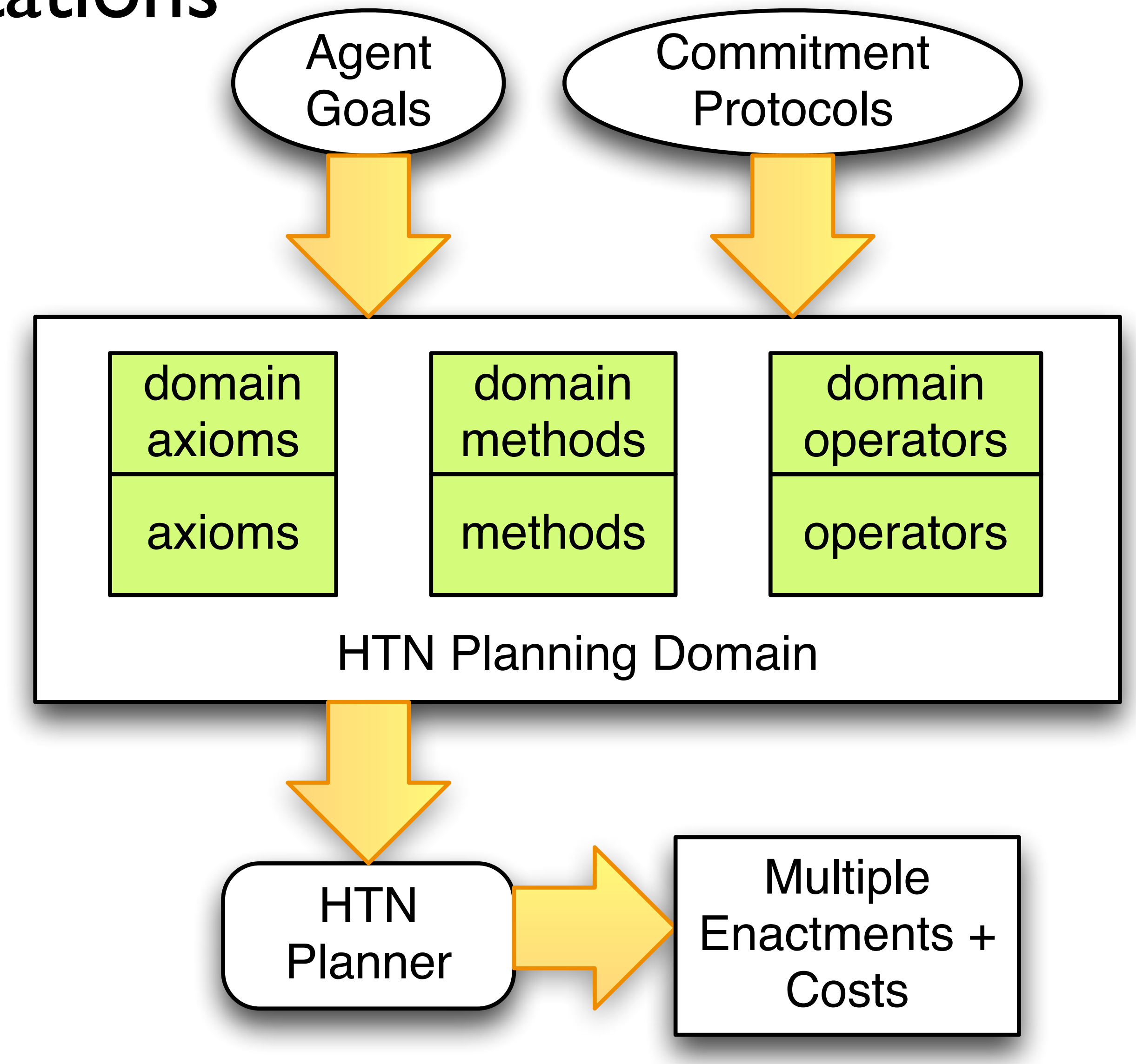
- Formalization of commitment protocols in terms of HTN planning
  - Axioms enforcing state transition model for goals and commitments
  - Planning Operators describing transitions (e.g. create, suspend, etc.)
  - HTN Methods for practical rules (e.g. entice, negotiate, etc.)



- Allows HTN planner to be used to validate commitment protocols

A first-order formalization

- Propositional formalization had several limitations
  - Limited expressivity
- New First-order formalization:
  - Domain independent axioms, methods and operators
  - Domain dependent axioms, costs, methods and operators
  - Useful patterns of behavior



Domain Independent Axioms & Operators

Commitment Axioms

$$null(C, Ct, \vec{Cv}) \leftarrow \neg var(C, Ct, \vec{Cv})$$
$$conditional(C, Ct, \vec{Cv}) \leftarrow active(C, Ct, \vec{Cv}) \wedge \neg p(C, Ct, \vec{Cv})$$
$$detached(C, Ct, \vec{Cv}) \leftarrow active(C, Ct, \vec{Cv}) \wedge p(C, Ct, \vec{Cv})$$

Goal Axioms

$$null(G, Gt, \vec{Gv}) \leftarrow \neg var(G, Gt, \vec{Gv})$$
$$\begin{aligned} inactiveG(G, Gt, \vec{Gv}) \leftarrow & \neg null(G, Gt, \vec{Gv}) \\ & \wedge \neg f(G, Gt, \vec{Gv}) \wedge \neg s(G, Gt, \vec{Gv}) \\ & \wedge \neg terminalG(G, Gt, \vec{Gv}) \wedge \neg suspendedG(G, Gt, \vec{Gv}) \\ & \wedge \neg activeG(G, Gt, \vec{Gv}) \end{aligned}$$

Commitment Operators

$$\begin{aligned} \langle & \textbf{operator}\ !\mathit{create}(C, Ct, De, Cr, \vec{Cv}), \\ & \textbf{pre}(\mathit{commitment}(C, Ct, De, Cr) \wedge \mathit{null}(C, Ct, \vec{Cv})), \\ & \textbf{del}(), \textbf{add}(var(C, Ct, \vec{Cv}))\rangle \end{aligned}$$
$$\begin{aligned} \langle & \textbf{operator}\ !\mathit{suspend}(C, Ct, De, Cr, \vec{Cv}), \\ & \textbf{pre}(\mathit{commitment}(C, Ct, De, Cr) \wedge \mathit{active}(C, Ct, \vec{Cv})), \\ & \textbf{del}(), \textbf{add}(\mathit{pending}(C, Ct, \vec{Cv}))\rangle \end{aligned}$$

Goal Operators

$$\begin{aligned} \langle & \textbf{operator}\ !\mathit{consider}(G, Gt, X, \vec{Gv}), \\ & \textbf{pre}(\mathit{goal}(G, Gt, X) \wedge \mathit{null}(G, Gt, \vec{Gv}) \wedge pg(G, Gt, \vec{Gv})), \\ & \textbf{del}(), \textbf{add}(\mathit{var}(G, Gt, \vec{Gv}))\rangle \end{aligned}$$
$$\begin{aligned} \langle & \textbf{operator}\ !\mathit{activate}(G, Gt, X, \vec{Gv}), \\ & \textbf{pre}(\mathit{goal}(G, Gt, X) \wedge \mathit{inactiveG}(G, Gt, \vec{Gv})), \\ & \textbf{del}(), \textbf{add}(\mathit{activatedG}(G, Gt, \vec{Gv}))\rangle \end{aligned}$$

Domain Dependent Definitions

- Axioms plus Domain-dependent operators

- Commitment Axioms

$$p(C, Ct, \vec{Cv}) \leftarrow commitment(C, Ct, De, Cr) \wedge \varphi$$
$$q(C, Ct, \vec{Cv}) \leftarrow commitment(C, Ct, De, Cr) \wedge \varkappa$$

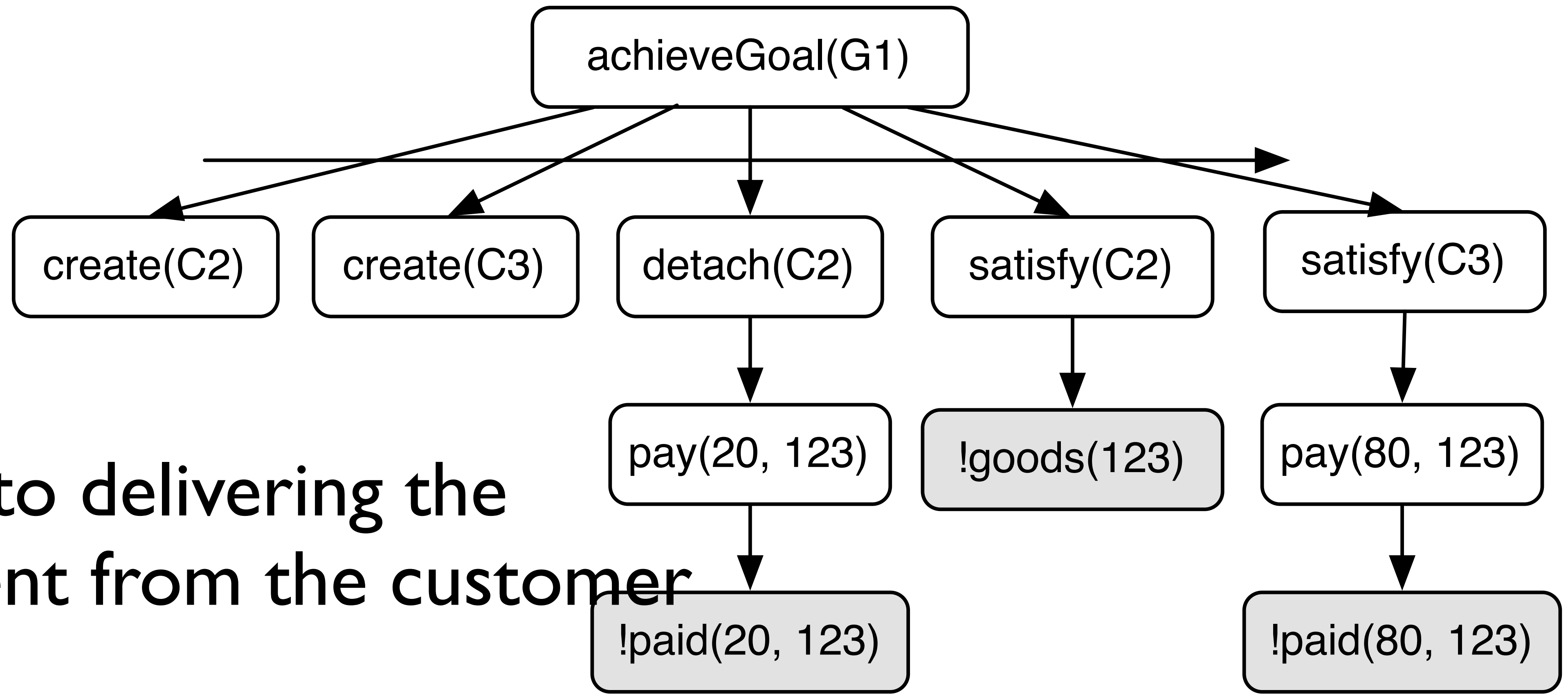
- Goal Axioms

$$pg(G, Gt, \vec{Gv}) \leftarrow goal(G, Gt, X) \wedge \varpi$$
$$s(G, Gt, \vec{Gv}) \leftarrow goal(G, Gt, X) \wedge \varsigma$$
$$f(G, Gt, \vec{Gv}) \leftarrow goal(G, Gt, X) \wedge \vartheta$$

- Axioms Generated automatically using a compilation tool

- Plus any domain-specific operators (e.g. purchase, ship, etc)

Patterns of Behavior



- Concession Pattern
  2 commitments
  - C2 - merchant commits to delivering the goods upon a \$20 payment from the customer
  - C3 - customer commits to pay \$80 upon receiving the goods
- By creating commitments C2 and C3, the customer has one possible way of achieving its goal

Conclusions and Future Work

- A FO formalization of goals and commitment protocols
  - Multiple interacting instances of the same goals and commitments
  - Piecemeal progress, concession, consolidation and compensation
- Future Work
  - Reasoning about probabilities
  - Modelling non-cooperative partners

Questions?