On The Role of Cases in Case-Based Planning

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Motivation

Search-control vs Domain knowledge

- Is there a relation between the **role** of the case and derivational/transformational adaptation approaches?
- There are several kinds of general purpose planners, can we present a unified view of the role of the cases for case-based planners build on top of those systems?
- General purpose planners presuppose a complete domain theory, can we use cases to overcome this limitation while preserving clear semantics for all kinds of general purpose planners?
- If we find a way to address this limitation, would we fall into the worse case scenario of (Nebel & Koehler, 1995)?

General Purpose vs Domain Specific (Case-Based) Planning

(Case-Based) Planning: finding a sequence of actions to achieve a goal

General purpose: symbolic descriptions of the problems and the domain. The (adaptation) generation rules are the same

Advantage: - opportunity to have clear semantics
Disadvantage: - symbolic description requirement

Domain Specific: The (adaptation) generation rules depend on the particular domain

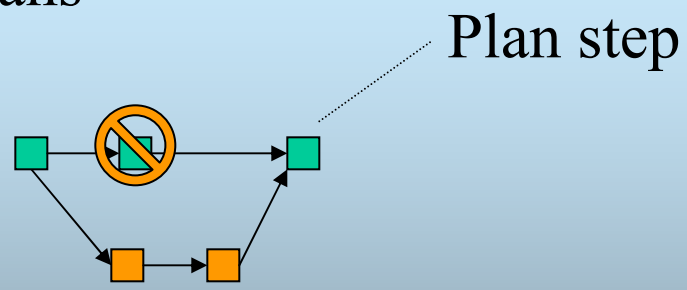
Advantage: - can be very efficient
Disadvantage: - lack of clear semantics
- knowledge-engineering for adaptation

Derivational vs. Transformational Adaptation

(Carbonnel, 1986)

- **Transformational adaptation**: structural transformations are made to the plans

Case:



- **Derivational transformation**:

Case: sequence of planning decisions that led to the plan:

Case Replay: re-applying those decisions relative to the new problem

Domain Specific: Chef

(Hammond, 1986)

- Cases contain cooking recipes (plans) and there are rules indicating how to transform pieces of the recipes

- Typical transformation rules will indicate alternative ingredients and what steps need to be added/changed to adapt the recipe

  Example: if using broccoli instead of beans the cooking time need to be adjusted.

- The cases contain domain-knowledge and transformational adaptation is performed

General Purpose

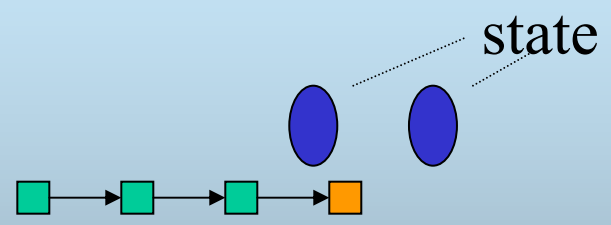
General purpose planners can be classified according to the space where the search is performed:

- state
- plan
- Hierarchies
- Disjunctive plans
- SAT

Role of cases
(what kind of search control?)

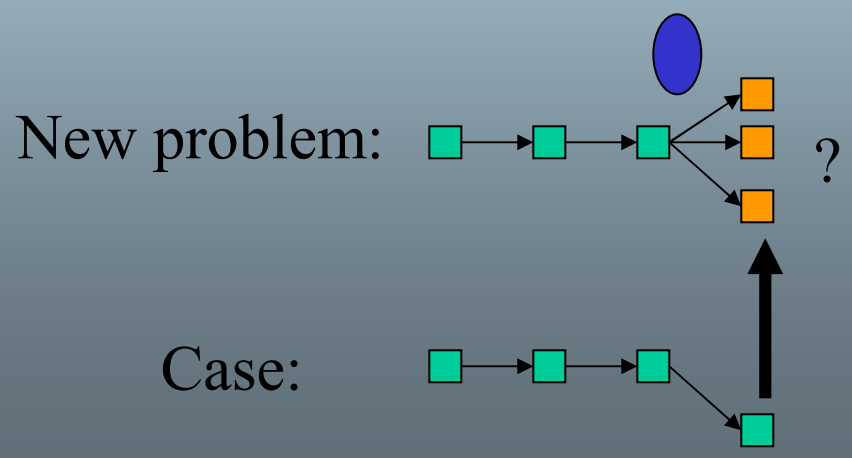
State-Space CBP Systems

- State-space planners transform the state of the world. These planners search for a sequence of transformations linking the starting state and a final state



(total order)

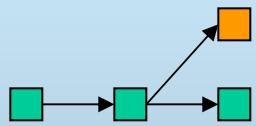
- Cases indicate sequence of state transformations



Derivational adaptation is used in Prodigy/Analogy (Veloso, 1994)

Plan-Space CBP Systems

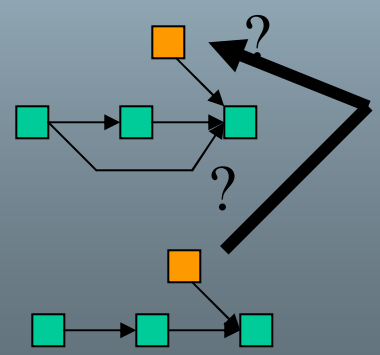
- Plan-space planners transform the plans. These planners search for a a plan satisfying certain conditions



(partial-order, least-commitment)

- Cases indicate sequences of plan transformations

New problem:

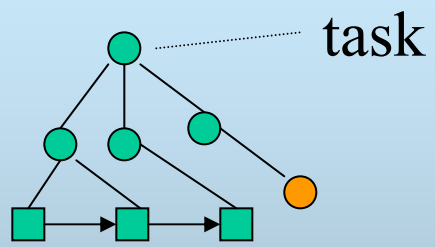


Case:

Derivational adaptation is used in derSNLP (Ihrig & Kambhampati, 1994)

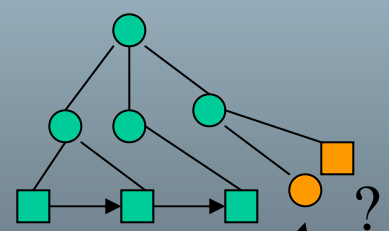
Hierarchical CBP Systems

- Hierarchical planners refine high-level tasks into simpler ones until eventually actions are obtained.

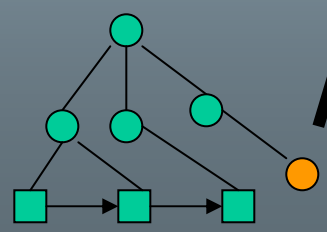


- Cases indicate how tasks are decomposed

New problem:



Case:



Derivational adaptation is used in Caplan/CbC (Muñoz-Avila et al, 1994)

Derivational/Transformational Adaptation vs. Domain Specific/General Purpose CBP

Domain specific CBP ⊘ **Transformational adaptation**

CoBRA
(Cunningham et al, 1994)

SPA
Adjust-plan

General purpose CBP ⊘ **Derivational adaptation**

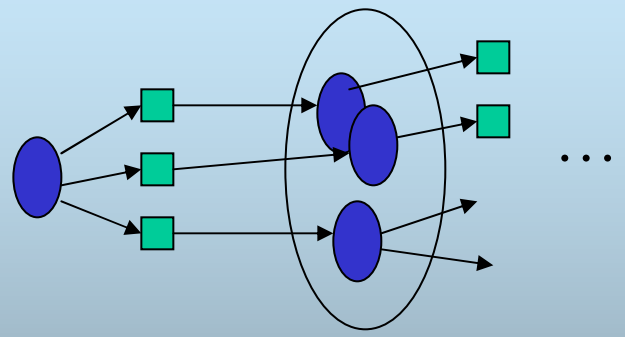
SPA
(Hanks & Weld, 1994)

Adjust-plan
(Gerevini & Serina, 2000)

CoBRA

Disjunctive CBP Systems

- Disjunctive planners transform a special structure that contains all possible states that can be obtained from the initial state



…

Graphplan (Blum & Furst, 1997)

- Adjust-plan (Gerevini & Serina, 2000):

  - uses the planning graph to determine a subset of actions in the plan that can be used to solve the new problem
  - Identifies inconsistencies between the new problem and the plan and pursues to repair the plan

Derivational/Transformational Adaptation vs. Role of the Cases

Domain Knowledge ⟷ **Transformational adaptation**

SPA
Adjust plan

SPA
Adjust-plan

Search Knowledge ⟷ **Derivational adaptation**

CoBRA

CoBRA

Where We Are

- Is there a relation between the **role** of the case and derivational/transformational adaptation approaches? Yes
- There are several kinds of general purpose planners, can we present a unified view of the role of the cases for case-based planners build on top of those systems?
- General purpose planners presuppose a complete domain theory, can we use cases to overcome this limitation while preserving clear semantics for all kinds of general purpose planners?
- If we find a way to address this limitation, would we fall into the worse case scenario of (Nebel & Koehler, 1995)?

Universal Classical Planning (UCP)

(Khambampati, 1997)

partially instantiated steps, plus constraints

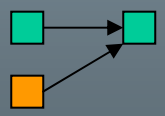
- Loop:
  - If the current *partial plan* is a solution, then exit
  - Nondeterministically choose a way to *refine* the plan

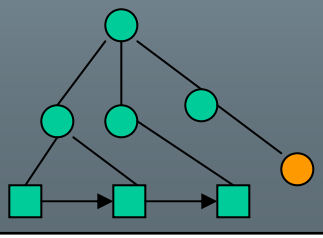
add steps & constraints

- Some of the possible **refinements**
  - Forward & backward state-space refinement
  - Plan-space refinement
  - Hierarchical refinements

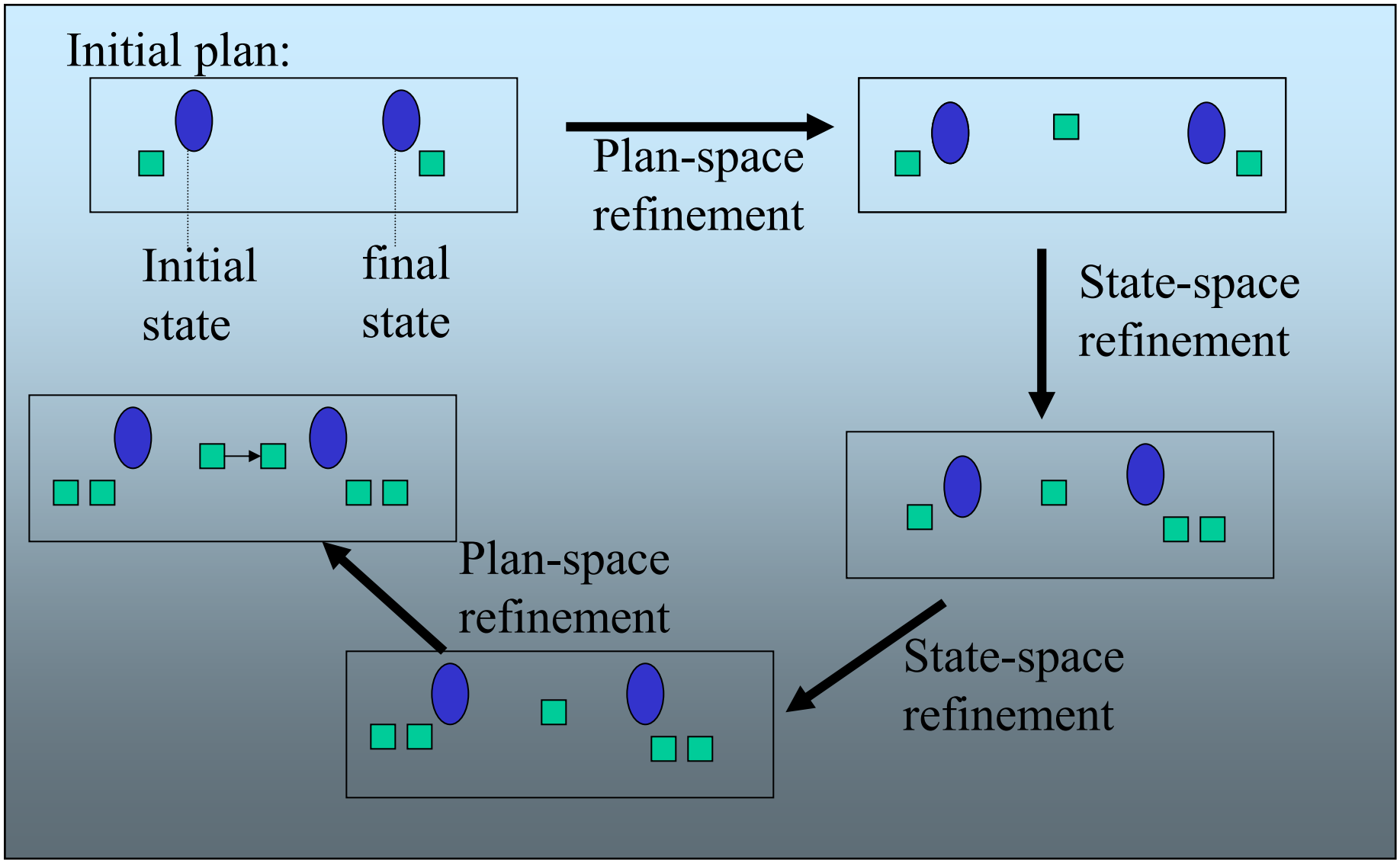
State-space

Plan-space





Abstract Example



DerUCP: Universal Derivational Analogy

(Chiu et al, 2002)

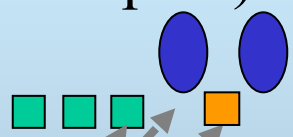
- A case is a ***derivational trace*** of the sequence of decisions made to obtain a plan

- The breakthrough was being able to define what a **refinement decision** is in UCP. A decision in DerUCP consists of:

  - The kind of refinement
    forward/backward state-space, plan-space, etc.
  - The *refinement goal*:
    what portion of the partial plan is relevant for applying the refinement
  - The *decision*:
    which refinement was chosen from among the alternative refinements

Example

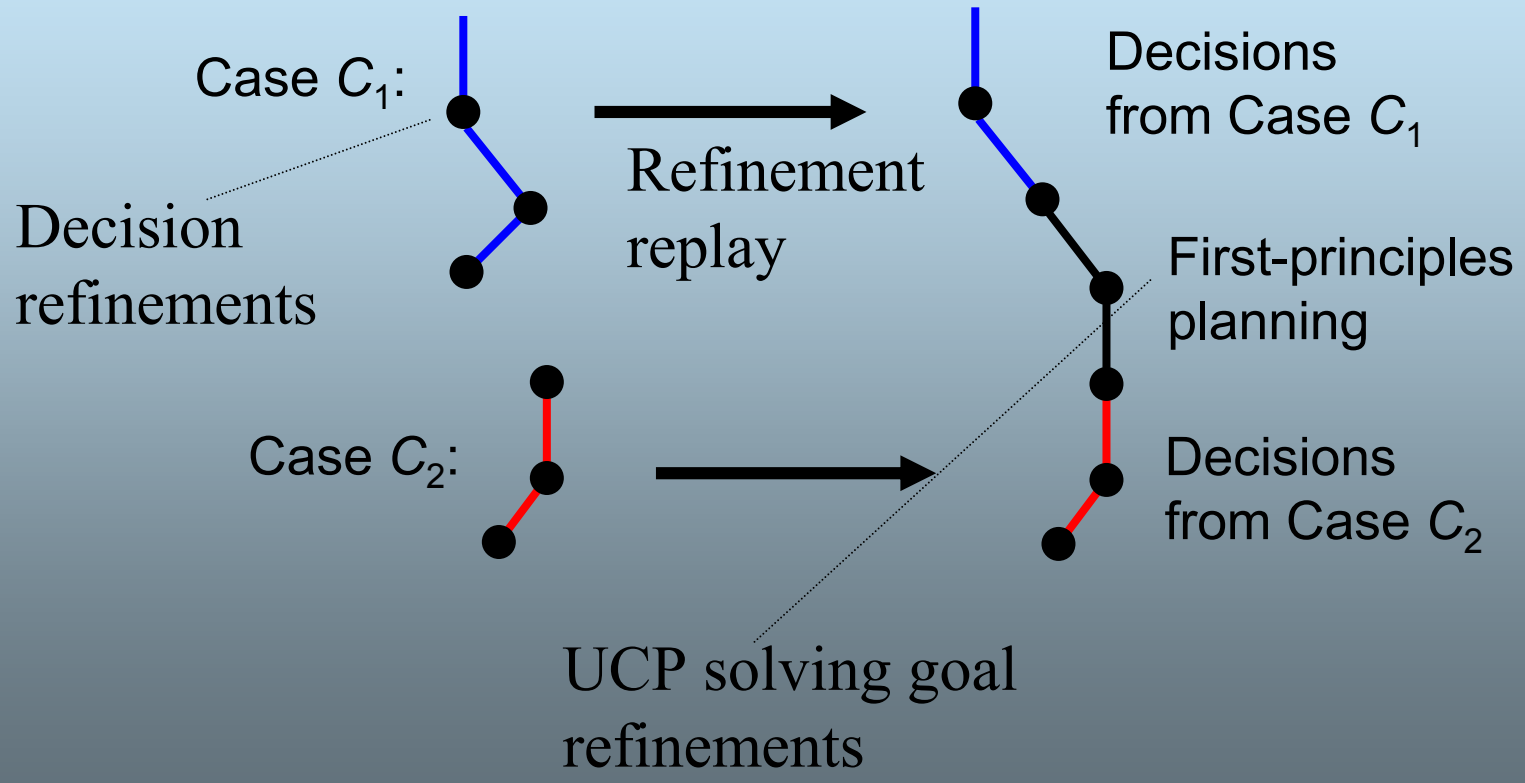
- Forward state-space refinement
  (add an action at the head of a plan)



- The refinement
  decision includes
  - Refinement goal:
    - the action-state *s* at the time the refinement was applied
  - Decision:
    - what step *t* was chosen (out of the set of all steps whose preconditions are satisfied by *s*)

Unified View of The Role of the Case in General Purpose CBP

Cases are sequences of refinement decisions



Nice, so what?

- "Conservative plan adaptation is harder (complexity-wise) than planning by first-principles" (Nebel & Koehler, 1995)

- An unified view allows to make analysis across multiple kinds of CBP systems

- "Derivational Adaptation for general purpose CBP systems is not conservative" (Chiu, 2002)

- "Derivational Adaptation for general purpose CBP systems can reduce the search space exponentially compared to planning by first-principles" (Chiu, 2002)

Where We Are

- There are several kinds of general purpose planners, can we present a unified view of the role of the cases for case-based planners build on top of those systems? Not yet!
  - Current view does not include disjunctive and SAT planning
  - Does not apply for transformational adaptation

Looking for a PhD thesis?

- General purpose planners presuppose a complete domain theory, can we use cases to overcome this limitation in a systematic way for **all** kinds of general purpose planners?

Why Enhancing The Domain Theory With Cases?

- In many practical applications, generating a complete domain theory is unpractical/unfeasible and episodic knowledge is available

Example: Some kinds of military operations where two kinds of knowledge are available (Muñoz et al, 1999):

- General guidelines and standard operational procedures which can be encoded as a (partial) domain theory

  general

- Whole compendium of actual operations and exercises which can be captured as cases

  specific

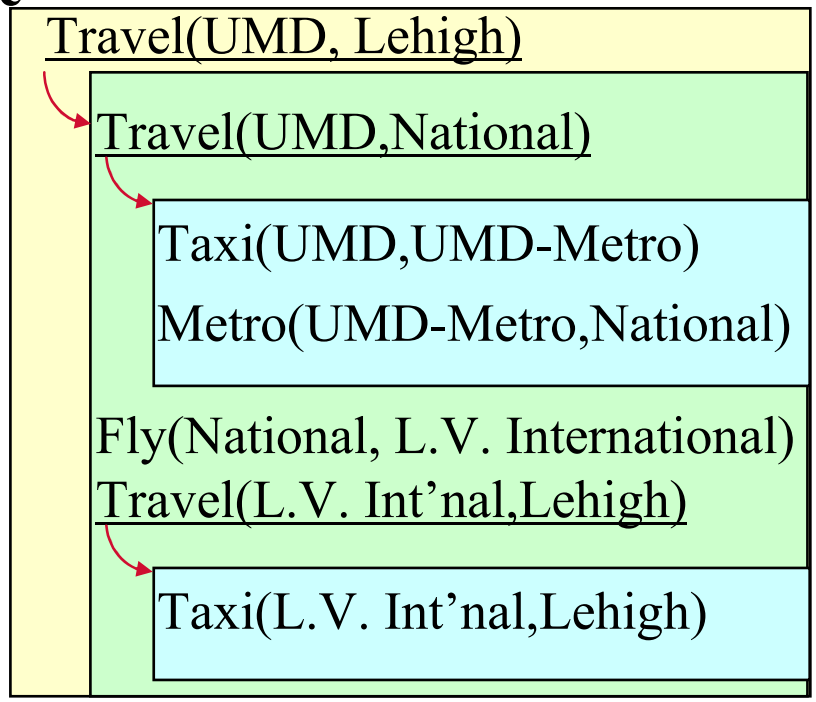
The SiN Algorithm

(Muñoz et al, 2000)

Hierarchical CBP system that combines domain knowledge and episodic knowledge (cases)

Knowledge source

domain



SiN: Knowledge Sources Algorithm

Domain

Methods denote generic task decompositions and *conditions* for selecting those decompositions:

Task: travel(A,B)

Decomposition:

travelC(A, Airp1)
travelIC(Airp1,Airp2)
travelC(Airp2, B)

Conditions:

in(A,City1)
in(B,City2)
airport(Airp1,City1)
airport(Airp2,City2)

Episodic

Cases denote concrete task decompositions:

Task: travelC(L.V. Int'nal,Lehigh)

Decomposition:

take(taxi, L.V. Int'nal,Lehigh)

Conditions:

enoughMoney()

SiN: Definitions

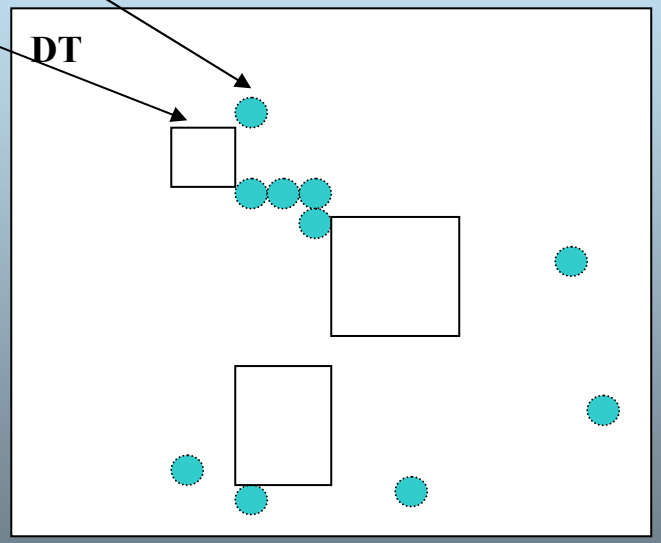
(Muñoz et al, 2001)

A case (T,ST,C) is an **instance** of a method (T',ST',C') if there is a substitution Θ such that T = T' Θ, ST = ST' Θ and C = C' Θ

We view cases as **instances** of unknown methods

SiN: Properties

Given a domain theory I and a case base B, a domain theory DT is **consistent** with (I∪B) if every case in B is an instance of a method in DT and I is a subset of DT



Theorem: SiN produces plans that are correct with respect to domain theories that are consistent with its knowledge base

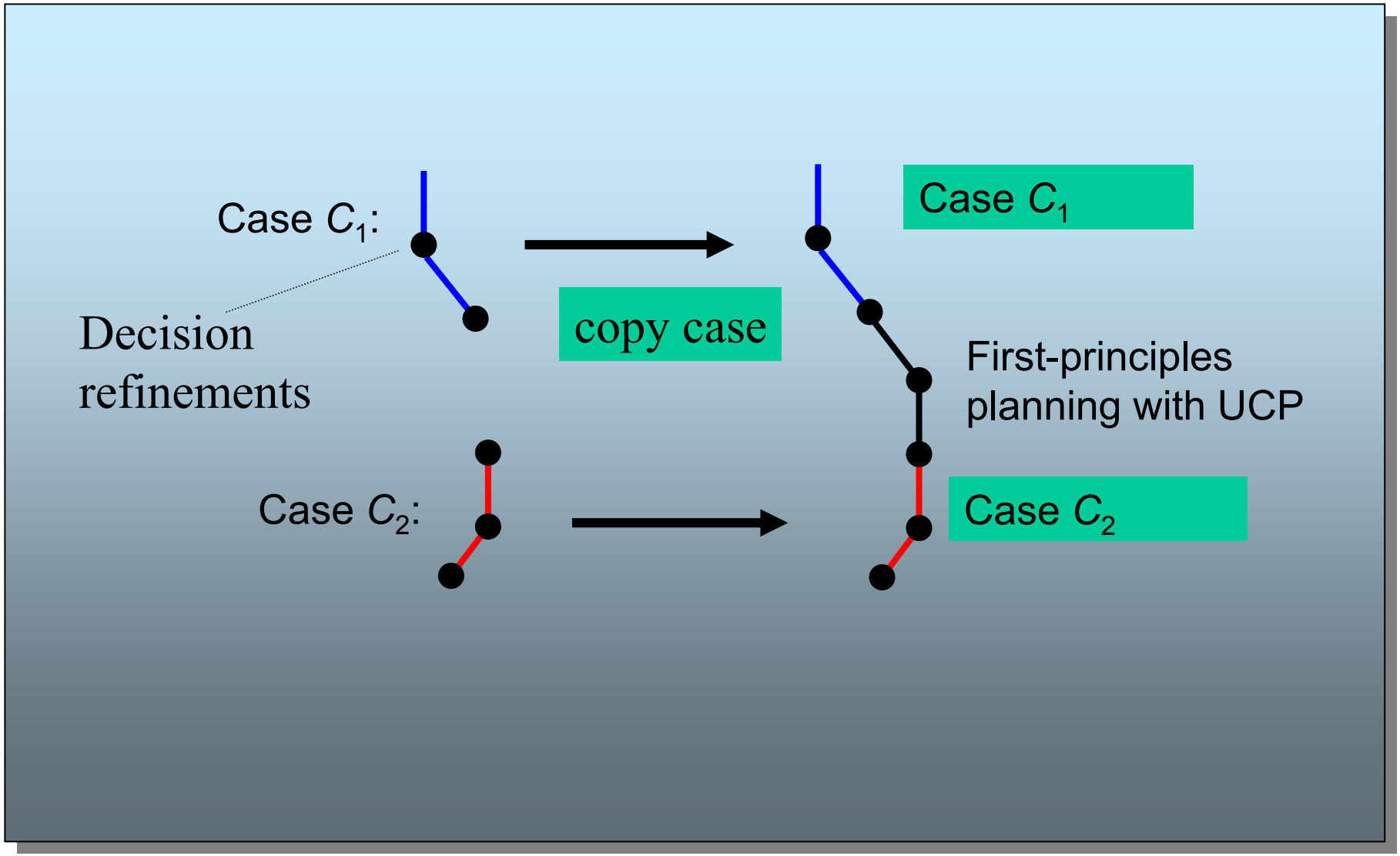
Ok. So this works for hierarchical plan generation. What about other forms of planning (e.g., combining partial and total order)?

Universal SiN

Idea: Use the notion of refinement decisions from DerUCP

- Tasks from SiN are a particular kind of refinement goal from DerUCP. Extend SiN to include other kinds of refinement goals
- Task decomposition is a particular kind of refinement. Extend SiN to include other kinds of refinements
- Extend decisions to include application of cases (concrete instances of methods or other knowledge artifacts as defined in UCP)

Universal SiN: Abstract Example



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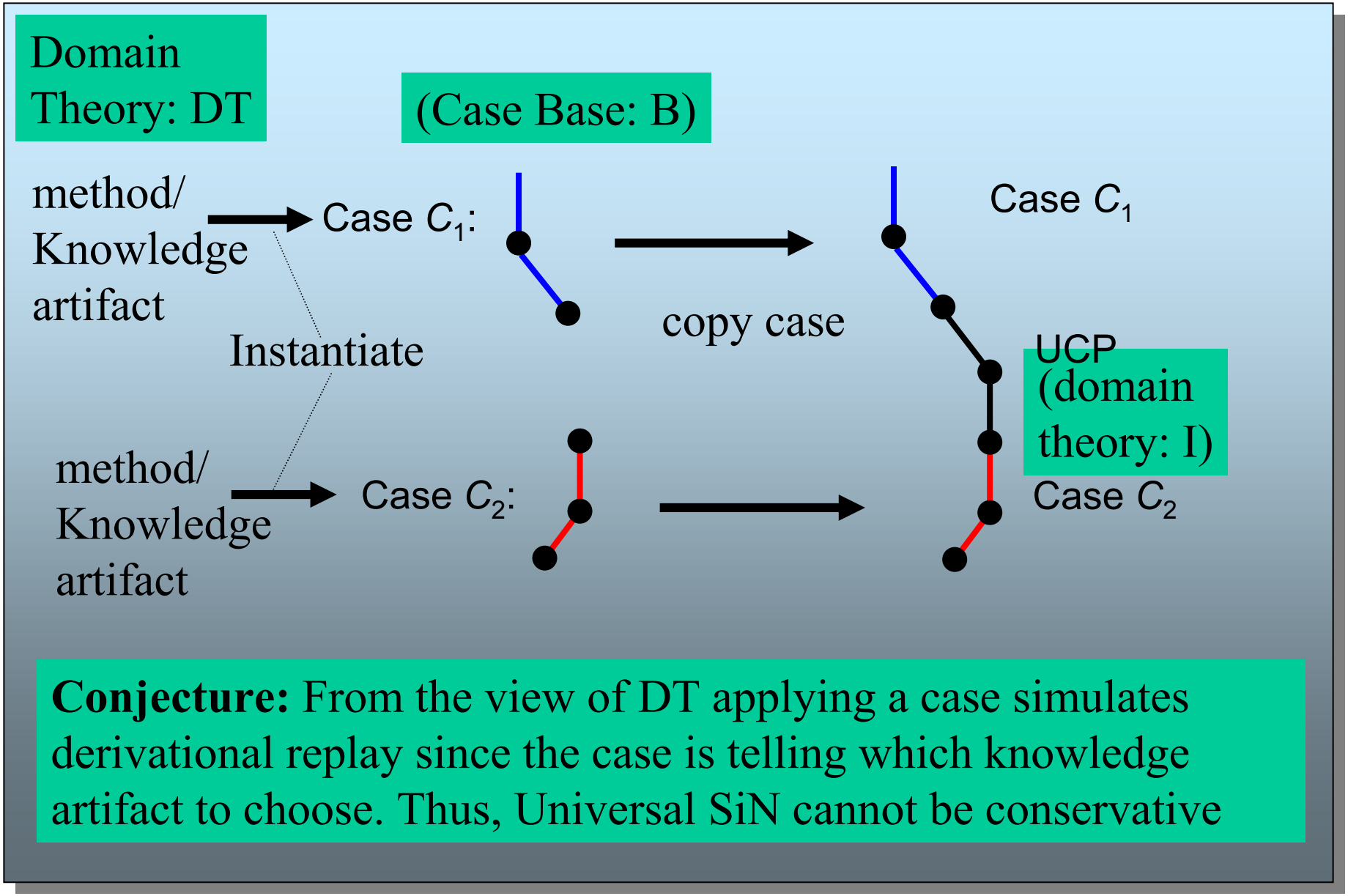
Looking for a PhD thesis?

- If we find a way to address this limitation, would we fall into the worse case scenario of (Nebel & Koehler, 1995)?

No, so far (conjecture)

Universal SiN Can Be Seen as derUCP



Conjecture: From the view of DT applying a case simulates derivational replay since the case is telling which knowledge artifact to choose. Thus, Universal SiN cannot be conservative

Future Research Directions

- Extensions to derUCP and Universal SiN
- Given a collection of methods (knowledge artifacts) I and cases B, what is the most general domain theory that we can obtain that is consistent with ($I \cup B$)

Instance of the problem: if only the case base CB is known

- Given a collection of cases for instances of derUCP, can we extract problem solving patterns?

Final Remarks

- The role of the cases is independent of whether the CBP system is general purpose or not. It is dependent if the adaptation is transformational or derivational
- For the derivational adaptation, the role of the cases can be seen as to provide refinement decisions. This view has important theoretical consequences
- Cases can help overcome the complete domain theory requirement of general purpose planners and still preserve clear semantics. We conjecture that this can be done without falling in worst case scenarios for plan adaptation