Artificial Intelligence and Human Planning

Lee Spector, Ph.D.
Cognitive Science
Hampshire College
Amherst, MA 01002
lspector@hampshire.edu

Joint work with:
Jordan Grafman
Mary Jo Rattermann

Overview

- AI planning systems
- Partial-order planning
- The D^1S^1 domain
- Planning and the frontal lobes
- The Chores experiment
- Planet H
- Conclusions

Planning Systems

Determine what to do in order to achieve a set of goals.

“What to do” usually means “which actions, in what order.”

Blocks-world.....Real-world agents

Many approaches, including:

- Generative
- Case-based
- Abstraction-based
- Reactive

...etc.

Action Representation

"STRIPS" operators consist of preconditions, add-lists, and delete-lists.

- The precondition states what must be true for the operator to be applicable.

- The add-list specifies things that the operator will make true.

- The delete-list specifies things that the operator will make false.

Example STRIPS-style Operator

Operator: Eat-Macaroni
Preconditions: Have-Macaroni, Hungry
Add-List: Macaroni-In-Stomach
Delete-List: Hungry, Have-Macaroni

The GPS/STRIPS Planning Algorithm

Achieve the conditions in the goal list one at a time.

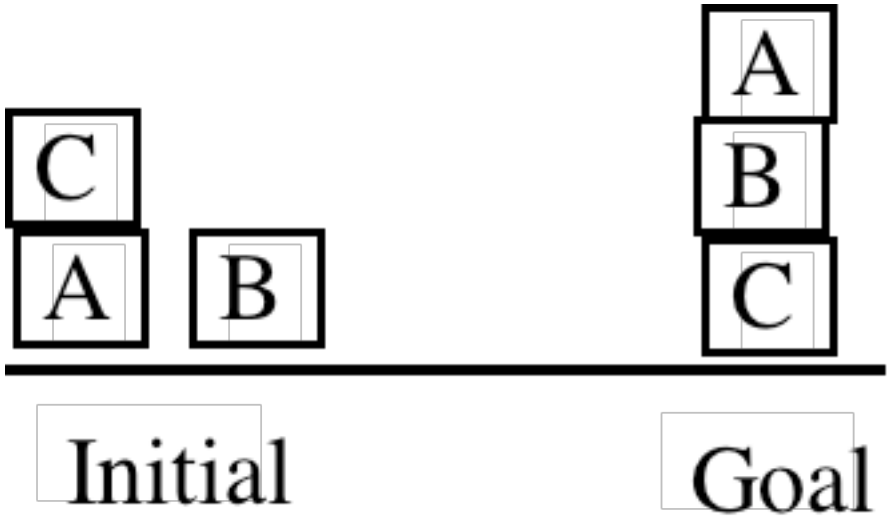
Each goal condition that is already true by the time it is considered can simply be skipped.

For goals that must be achieved, find an operator with the goal condition in its add-list and recursively achieve all of its preconditions. Then “apply” the operator by changing the state of the world according to its add- and delete-lists.

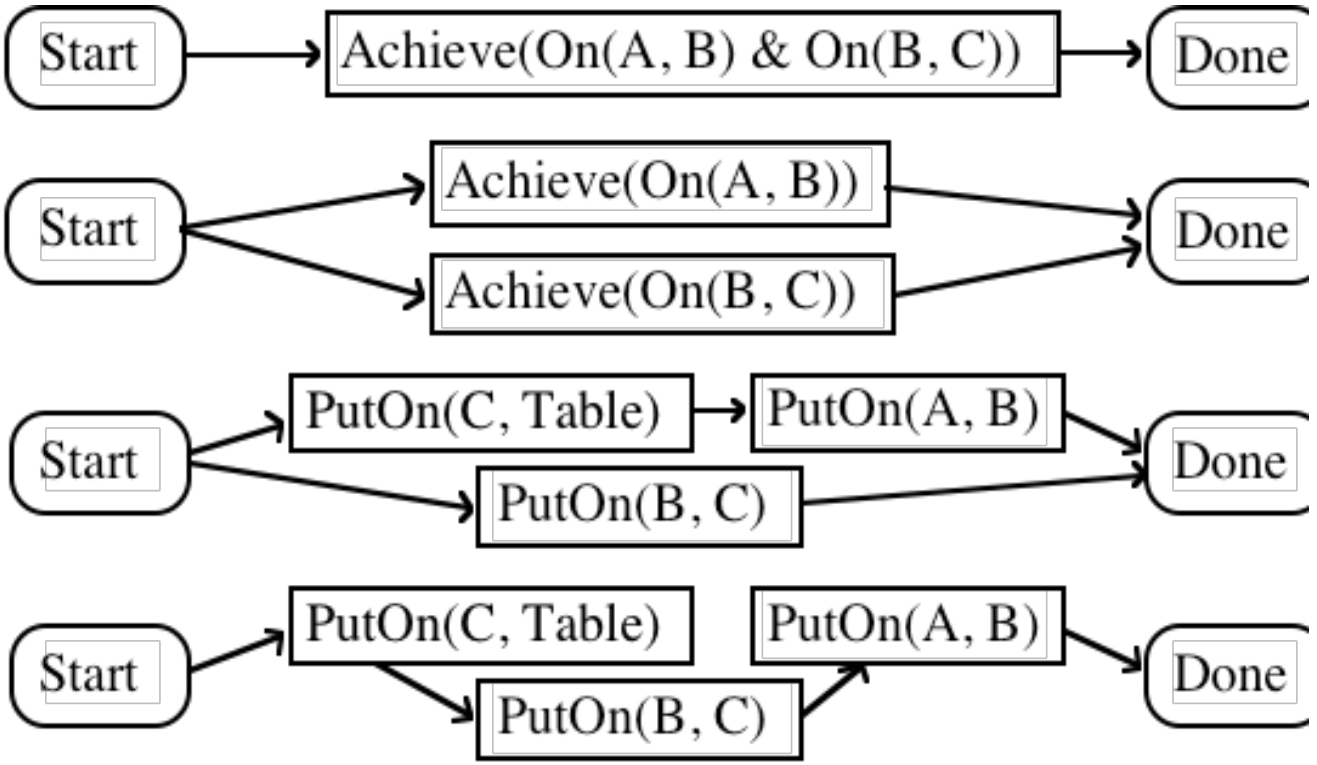
Partial-order Planning

- Represent partial plans as partially-ordered sets of plan steps
- Used in most "state of the art" AI planning systems
- **Not** used in most neuropsychological models of planning

The Sussman Anomaly



Solving the Sussman Anomaly with Partially Ordered Partial Plans



The D^1S^1 Domain (Barrett & Weld 1993)

- An artificial domain
- All operators have the following form:

Operator:

Action:	A_i
Preconditions:	$\{I_i\}$
Add:	$\{G_i\}$
Delete:	$\{I_{i-1}\}$

D^1S^1 Complexity (Barrett & Weld 1993)

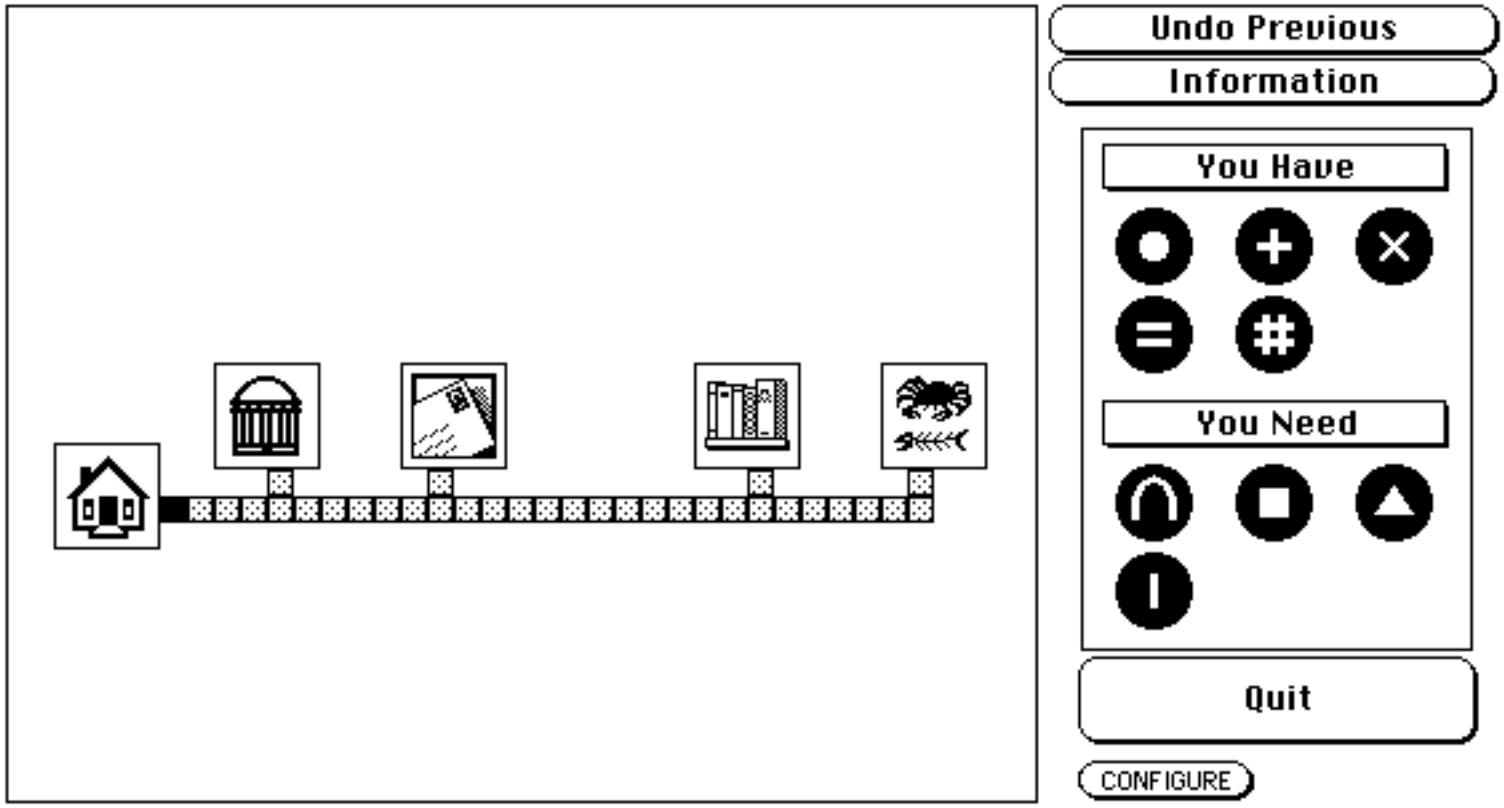
- Expected time to solve an instance of D^1S^1 rises **exponentially** with the number of goals for a "standard" total-order planner (*TOCL*).

- Expected time to solve an instance of D^1S^1 rises **linearly** with the number of goals for a "standard" partial-order planner (*POCL*).

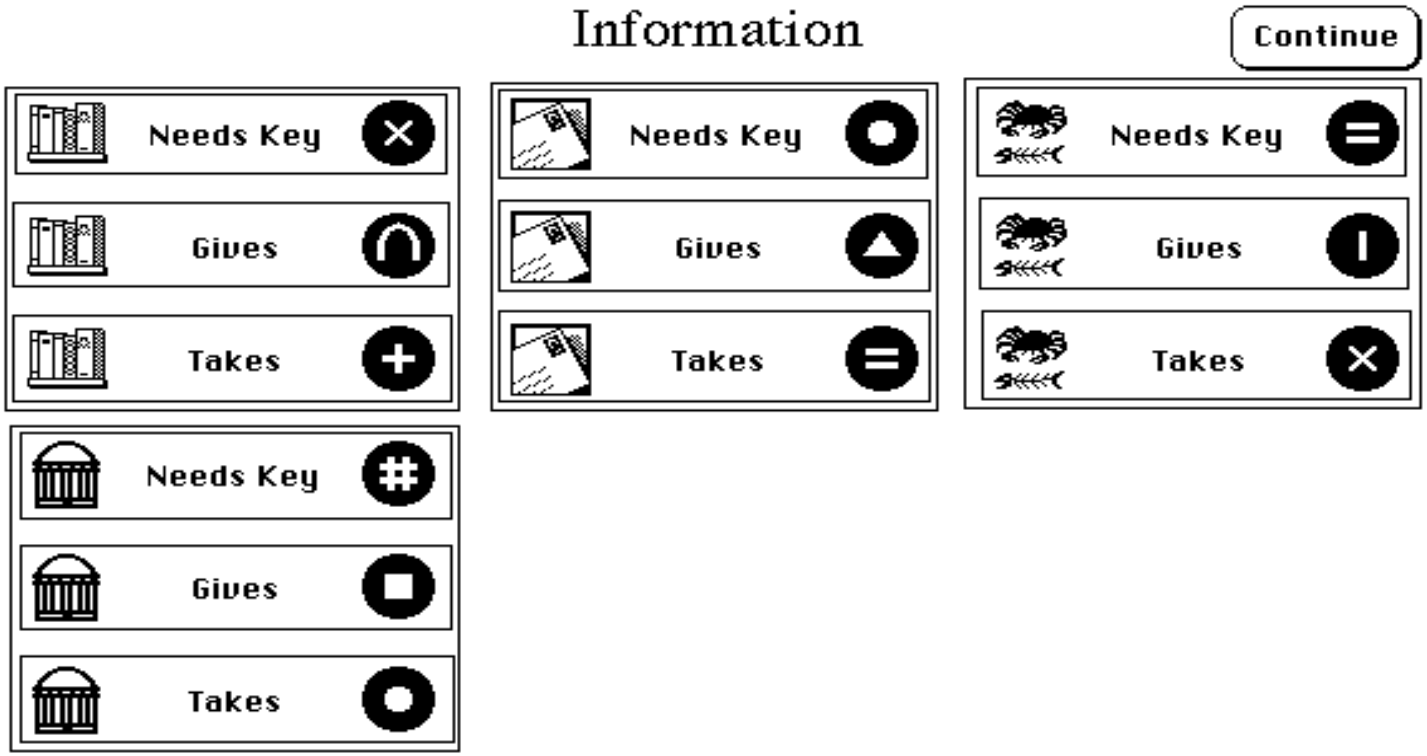
Planning and the Frontal Lobes

- Frontal lobe lesion patients exhibit planning deficits.
- Several researchers have hypothesized that planning is a frontal lobe function (Grafman, Shallice, Levinson...)
- Human frontal lobes are not fully mature until approximately age 11.

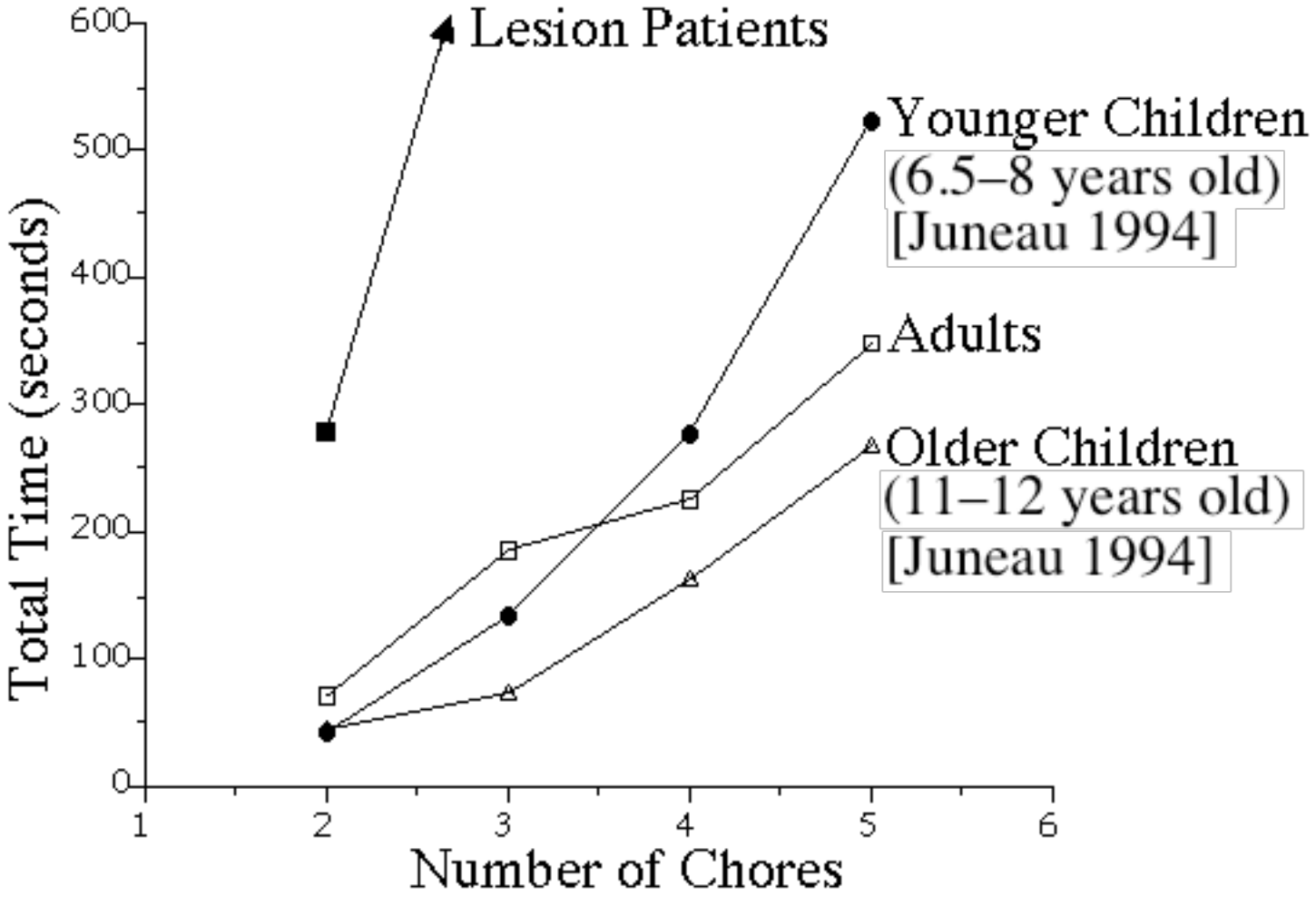
The Chores Experiment



Operators in the Chores Experiment



Early D^1S^1 Chores Results, Total Time



Additional D^1S^1 Chores Results

Additional measures:

- "Item Info" viewing time
- analysis of "Undo" patterns

Additional data:

- Swarthmore College
- NIH/NINDS

	Total Time	**Item Info Time**	**Undo Pattern**
Normal Adults	linear	linear	partial order
Older Children	linear	exponential	partial order
Young Children	exponential	exponential	total order
Lesioned Adults	exponential	exponential	?

Analysis

- Task completion times for **normal adults** and **older children** on D^1S^1 tasks rise **linearly** with the number of goals.

- Task completion times for **younger children** on D^1S^1 tasks rise **non-linearly** with the number of goals.

- The performance **frontal lobe lesion patients** is poor; task completion times appear to rise **non-linearly** with the number of goals (but more data is needed).

Interpretation

- The performance of normal adults and older children is similar to that of *partial order* AI planning systems.

- The performance of younger children and frontal lobe lesion patients is similar to that of *total order* AI planning systems.

One explanation:

- Normal adults and older children represent partial plans as *partial* orders.
- Younger children and frontal lobe lesion patients represent partial plans as *total* orders.

Planet H

Planning **E**xperiment **T**estbed for **H**umans

Goals:

- Support pure plan construction/modification; no conflation with plan execution (to allow better comparison to analytical results).

- Support construction of plans in any order.

- Support planning with durations.

- Simple text-based experiment configuration files.

Planet H Specifications

```
(defgoals "Pictures" "Bouquet")

(definventory "Invitation" "Money")

(defaction
  :name "Go Shopping For Wedding"
  :requires ("Money")
  :gives ("Dress" "Gift")
  :takes ("Money")
  :duration 1)

(show-final-inventory)
```

Planet H Screen

Initial Inventory
Invitation, Money

Goals
Pictures, Bouquet

Actions

Go Shopping For Wedding
Keys: Money
Gives: Dress, Gift
Takes: Money

Watch Marriage Ceremony
Keys: Party, Program
Gives: Reception Details
Takes: Program

Prepare For Wedding
Keys: Dress
Gives: Camera, Film
Takes:

The Plan

Final Inventory
Invitation, Money

Planet H Protocols

```
26 action chosen: Go to the Church
26 added action at step 1
26 current plan state:
  action: Go to the Church
  comment:  Can't do it! (Missing Film, Camera, Dress)
  --
  final inventory: Invitation, Money
40 action chosen: Go Shopping For Wedding
40 added action at step 1
40 current plan state:
  action: Go Shopping For Wedding
  comment: Got: Dress, Gift
           Gave up: Money
  --
  action: Go to the Church
  comment:  Can't do it! (Missing Film, Camera)
  --
  final inventory: Gift, Dress, Invitation
```

Specific Conclusions

- Human planners with intact, fully developed frontal lobes appear to be partial-order planners.
- Human planners with damaged or immature frontal lobes appear to be total-order planners.
- Other dimensions of planning algorithms (e.g. systematicity) can be studied using a similar methodology.
- Planet H supports the generalization of this methodology to other aspects of planning.

General Conclusions

- AI results can guide the design of well-structured neuropsychology experiments that produce real results.
- Careful neuropsychological studies can help to guide AI.
- Performance curves provide one solid point of contact between disciplines.
- We face several challenges in combining results from AI with results from neuropsychology, but we stand to gain much if we meet these challenges.