Lecture slides for
Automated Planning: Theory and Practice

Review for the Final Exam

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CMSC 722, AI Planning
University of Maryland, Spring 2008

What We've Covered

- Chapter 1: Introduction
- Chapter 2: Representations for Classical Planning
- Chapter 3: Complexity of Classical Planning
- Chapter 4: State-Space Planning
- Chapter 5: Plan-Space Planning
- Chapter 6: Planning-Graph Techniques
- Chapter 7: Propositional Satisfiability Techniques
- Chapter 9: Heuristics in Planning
- Chapter 10: Control Rules in Planning*
- Chapter 11: Hierarchical Task Network Planning*
- Chapter 16: Planning based on MDPs
- Chapter 17: Planning based on Model Checking
- Chapter 14: Temporal Planning*
- Chapter 15: Planning and Resource Scheduling*
- Chapter 20: Planning in Robotics*
- Chapter 23: Planning in the Game of Bridge*

* These weren't on the midterm

No questions on this chapter

Chapter 1: Introduction and Overview

- 1.1: First Intuitions on Planning
- 1.2: Forms of planning
- 1.3: Domain-Independent Planning
- 1.4: Conceptual Model for Planning
- 1.5: Restricted Model
- 1.6: Extended Models
- 1.7: A Running Example: Dock-Worker Robots

No questions on Chapter 1

2: Representations for Classical Planning

- 2.1: Introduction
- 2.2: Set-Theoretic Representation
  - 2.2.1: Planning Domains, Problems, and Solutions
  - 2.2.2: State Reachability
  - 2.2.3: Stating a Planning Problem
  - 2.2.4: Properties of the Set-theoretic Representation
- 2.3: Classical Representation
  - 2.3.1: States
  - 2.3.2: Operators and Actions
  - 2.3.3: Plans, Problems, and Solutions
  - 2.3.4: Semantics of Classical Representations

2: Representations for Classical Planning

- 2.4: Extending the Classical Representation
  - 2.4.1: Simple Syntactical Extensions
  - 2.4.2: Conditional Planning Operators
  - 2.4.3: Quantified Expressions
  - 2.4.4: Disjunctive Preconditions
  - 2.4.5: Axiomatic Inference
  - 2.4.6: Function Symbols
  - 2.4.7: Attached Procedures
  - 2.4.8: Extended Goals
- 2.5: State-Variable Representation
  - 2.5.1: State Variables
  - 2.5.2: Operators and Actions
  - 2.5.3: Domains and Problems
  - 2.5.4: Properties
- 2.6: Comparisons

See Chapters 10, 11, …

Chapter 3: Complexity of Classical Planning

- 3.1: Introduction
- 3.2: Preliminaries
- 3.3: Decidability and Undecidability Results
- 3.4: Complexity Results
  - 3.4.1: Binary Counters
  - 3.4.2: Unrestricted Classical Planning
  - 3.4.3: Other results
- 3.5: Limitations

No questions on this chapter

Chapter 4: State-Space Planning

- 4.1: Introduction
- 4.2: Forward Search
  - 4.2.1: Formal Properties
  - 4.2.2: Deterministic Implementations
- 4.3: Backward Search
- 4.4: The STRIPS Algorithm
- 4.5: Domain-Specific State-Space Planning
  - 4.5.1: The Container-Stacking Domain
  - 4.5.2: Planning Algorithm

soundness & completeness,
loop checking,
relevant actions

My lecture discussed block stacking, which is nearly the same

Chapter 5: Plan-Space Planning

- 5.1: Introduction
- 5.2: The Search Space of Partial Plans
- 5.3: Solution Plans
- 5.4: Algorithms for Plan Space Planning
  - 5.4.1: The PSP Procedure
  - ~~5.4.2: The PoP Procedure~~
- ~~5.5: Extensions~~
- 5.6: Plan Space Versus State Space Planning

flaws,
causal links,
resolvers

Chapter 6: Planning-Graph Techniques

- 6.1: Introduction
- 6.2: Planning Graphs
  - 6.2.1: Reachability Trees
  - 6.2.2: Reachability with Planning Graphs
  - 6.2.3: Independent Actions and Layered Plans
  - 6.2.4: Mutual Exclusion Relations
- 6.3: The Graphplan Planner
  - 6.3.1: Expanding the Planning Graph
  - 6.3.2: Searching the Planning Graph
  - 6.3.3: Analysis of Graphplan
- 6.4: Extensions and Improvements of Graphplan
  - 6.4.1: Extending the Language
  - 6.4.2: Improving the Planner
  - 6.4.3: Extending the Independence Relation

pay more attention to my notes than to the chapter

Didn't cover

7: Propositional Satisfiability Techniques

- 7.1: Introduction
- 7.2: Planning problems as Satisfiability problems
  - 7.2.1: States as propositional formulas
  - 7.2.2: State transitions as propositional formulas
  - 7.2.3: Planning problems as propositional formulas
- 7.3: Planning by Satisfiability
  - 7.3.1: Davis-Putnam
  - 7.3.2: Stochastic Procedures
- 7.4: Different Encodings
  - 7.4.1: Action Representation
  - 7.4.2: Frame axioms

I won't ask you about these.

Didn't cover

Chapter 10: Control Rules in Planning

- Intro to Part III: Heuristics and Control Strategies

- 10.1: Introduction
- 10.2: Simple Temporal Logic
- 10.3: Progression
- 10.4: Planning Procedure
- 10.5: Extensions
- ~~10.6: Extended Goals~~

Chapter 11: HTN Planning

- 11.1: Introduction
- 11.2: STN Planning
  - 11.2.1: Tasks and Methods
  - 11.2.2: Problems and Solutions
- 11.3: Total-Order STN Planning
- 11.4: Partial-Order STN Planning
- ~~11.5: HTN Planning~~
- 11.6: Comparisons
  - ~~11.6.1: HTN Planning Versus STN Planning~~
  - 11.6.2: HTN Methods Versus Control Rules
- 11.7: Extensions
  - 11.7.1: Extensions from Chapter 2
  - ~~11.7.2: Additional Extensions~~
- ~~11.8: Extended Goals~~

Chapter 16: Planning Based on MDPs

- 16.1: Introduction
- 16.2: Planning in Fully Observable Domains
  - 16.2.1: Domains, Plans, and Planning Problems
  - 16.2.2: Planning Algorithms
- 16.3: Planning under Partial Observability
  - 16.3.1: Domains, Plans, and Planning Problems
  - 16.3.2: Planning Algorithms
- ~~16.4: Reachability and Extended Goals~~

17: Planning based on Model Checking

- 17.1: Introduction
- 17.2: Planning for Reachability Goals
  - 17.2.1: Domains, Plans, and Planning Problems
  - 17.2.2: Planning Algorithms
- 17.3: Planning for Extended Goals
  - 17.3.1: Domains, Plans, and Planning Problems
  - 17.3.2: Planning Algorithms
  - 17.3.3: Beyond Temporal Logics
- 17.4: Planning under Partial Observability
  - 17.4.1: Domains, Plans, and Planning Problems
  - 17.4.2: Planning Algorithms
- 17.5: Planning as Model Checking vs. MDPs

Chapter 9: Heuristics in Planning

- 9.1: Introduction
- 9.2: Design Principle for Heuristics: Relaxation
- 9.3: Heuristics for State-Space Planning
  - 9.3.1: State Reachability Relaxation
  - 9.3.2: Heuristically Guided Backward Search
  - 9.3.3: Admissible State-Space Heuristics
  - 9.3.4: Graphplan as a Heuristic-Search Planner
- 9.4: Heuristics for Plan-Space Planning
  - 9.4.1: Flaw-Selection Heuristics
  - ~~9.4.2: Resolver-Selection Heuristics~~

Chapter 14: Temporal Planning

- 14.1: Introduction
- 14.2: Planning with Temporal Operators
  - 14.2.1: Temporal Expressions and Temporal Databases
  - 14.2.2: Temporal Planning Operators
  - 14.2.3: Domain axioms
  - 14.2.4: Temporal Planning Domains, Problems and Plans
  - 14.2.5: Concurrent Actions with Interfering Effects
  - 14.2.6: A Temporal Planning Procedure
- 14.3: Planning with Chronicles
  - 14.3.1: State Variables, Timelines and Chronicles
  - 14.3.2: Chronicles as Planning Operators
  - 14.3.3: Chronicle Planning Procedures
  - 14.3.4: Constraint Management in CP
  - 14.3.5: Search Control in CP

15: Planning and Resource Scheduling

- 15.1: Introduction
- 15.2: Elements of Scheduling Problems
  - 15.2.1: Actions
  - 15.2.2: Resources
  - 15.2.3: Constraints and Cost Functions
- 15.3: Machine Scheduling Problems
  - 15.3.1: Classes of Machine Scheduling Problems
  - 15.3.2: Complexity of Machine Scheduling
  - 15.3.3: Solving Machine Scheduling Problems
  - 15.3.4: Planning and Machine Scheduling
- 15.4: Integrating Planning and Scheduling
  - 15.4.1: Representation
  - 15.4.2: Detecting Resource Conflicts
  - 15.4.3: Managing Resource-Conflict Flaws

I won't ask you about these.

20. Planning in Robotics

- I might ask something about roadmaps
- I won't ask questions on the rest of the chapter

The Exam

- Friday, May 19, 10:30-12:30
- Open book, open notes
- During the exam, you'll be able to choose one of the following:
  - Midterm 20%, Final 50%, Project 30%
  - Midterm 30%, Final 40%, Project 30% (default)
  - Midterm 40%, Final 30%, Project 30%

Miscellaneous

- Sample exams:
  - Go to the home page, and click on “private materials”
- If you have questions, send email
  - Better to cc it to the entire class
  - I’ll be at a conference in Portugal, and won’t have good email access
- I’ll probably send you email about additional sections of the book that you won’t need to know