ODO: A Constraint-based Scheduling Shell

J. Christopher Beck

Enterprise Integration Laboratory, University of Toronto

Philosophy

Approach

- Constraint-Based Problem Solving

Status

Philosophy

Create a tool for scheduling research

- Model and solve real-world problems
- Test a variety of (constraint-based) scheduling methodologies

Therefore:

- General, extensible input language for describing problems
- General, extensible language for describing scheduling policies

Therefore, ODO is a scheduling “interpreter”. No set way to do scheduling. Heuristic follows our model, with parameters set at run-time

Constraint-based Reasoning

Variables

- Domains - typically discrete and finite
- Assigned values (or sets of values) in solutions

Constraints

- Attached to variables
- Restrict mutually compatible values on variables

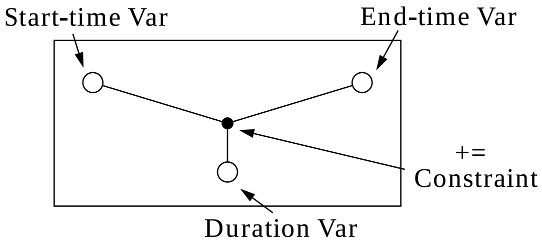
Net result: A “Constraint Graph”

Constraint Model of Scheduling

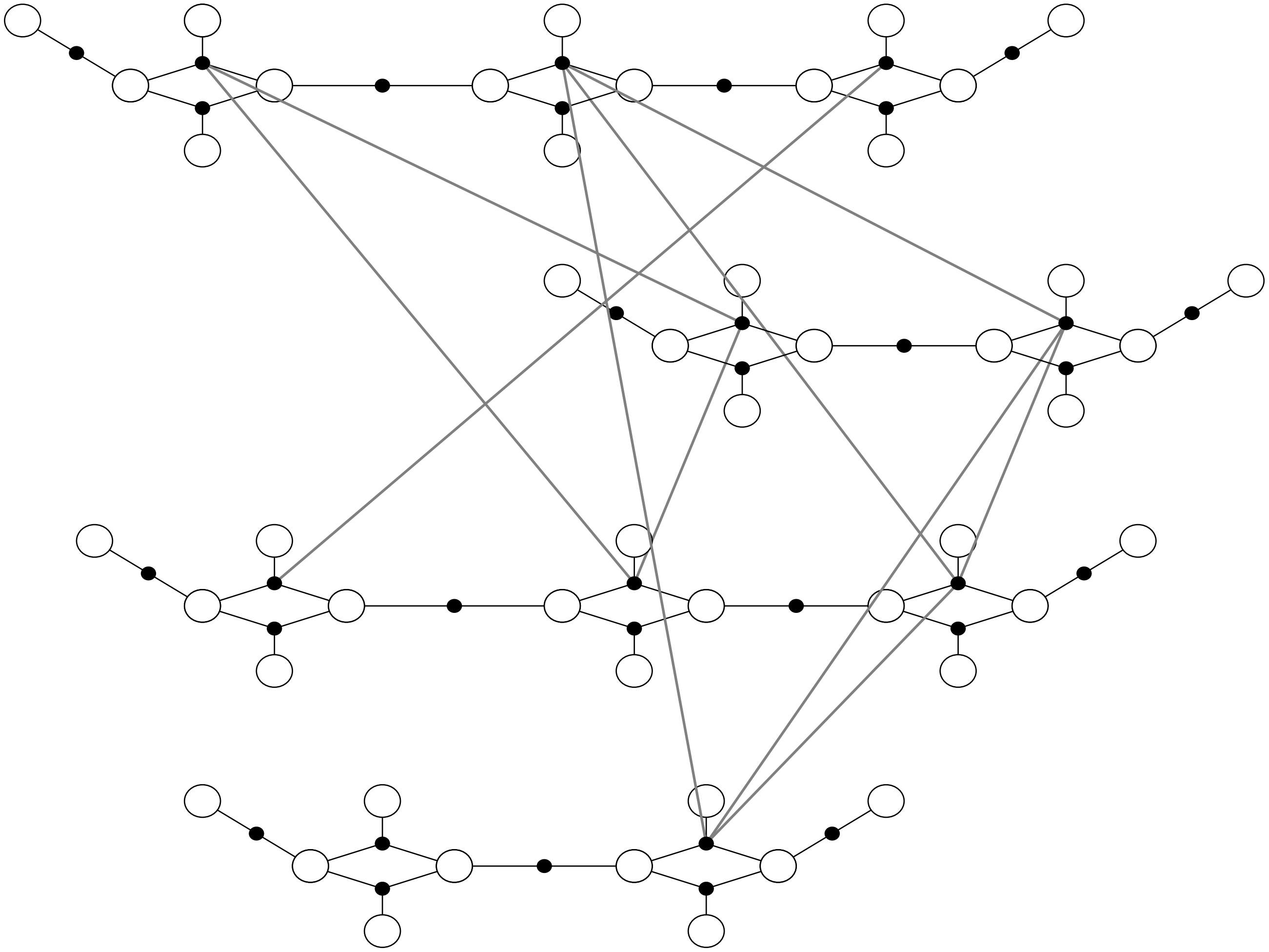
Variables are the start- and end-times of activities, and the resource assignments for activities (if any)

Constraints restrict the acceptable values for the variables

- Temporal constraints
  - ✯ start-time(T1) + duration(T1) = end-time(T1)
  - ✯ start-time(T2) >= end-time(T1)
- Resource constraints
  - ✯ The assigned resource must be allocated to the activity from its start-time to its end-time



Resulting Constraint Graph



Search Styles in CSP

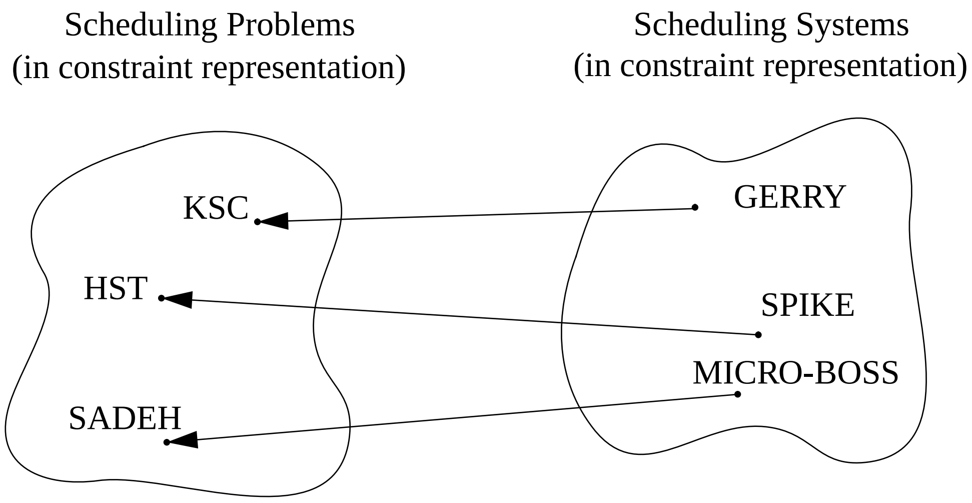
Constructive

- start with “clean slate”
- may or may not be systematic
- Backtracking: a systematic approach (compare to branch and bound)

Repair-based

- Start with an initial assignment to all variables
- Use some metric (objective function) to measure quality of problem states
- Incrementally assign values until good enough solution is found
- Variations: Hill-climbing, simulated annealing (also genetic algorithms)

So We Have:



Scheduling Problems
(in constraint representation)

Scheduling Systems
(in constraint representation)

KSC

HST

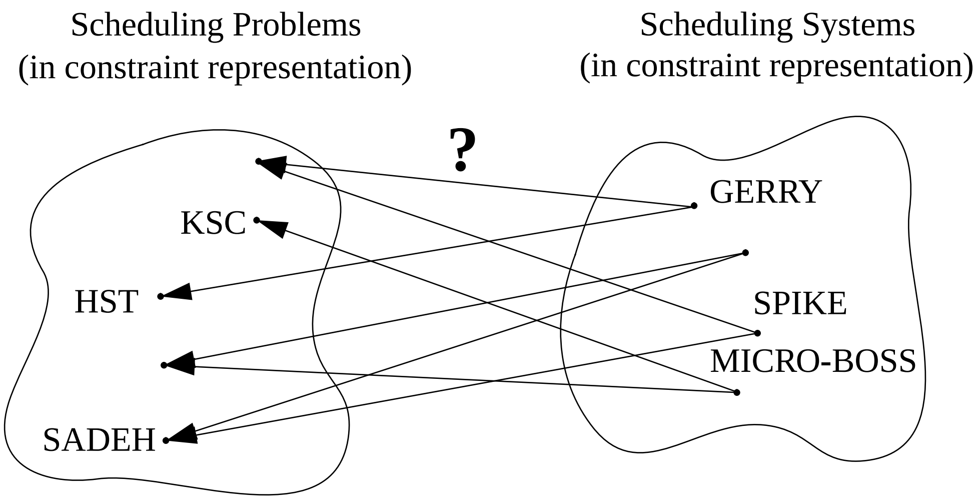
SADEH

GERRY

SPIKE

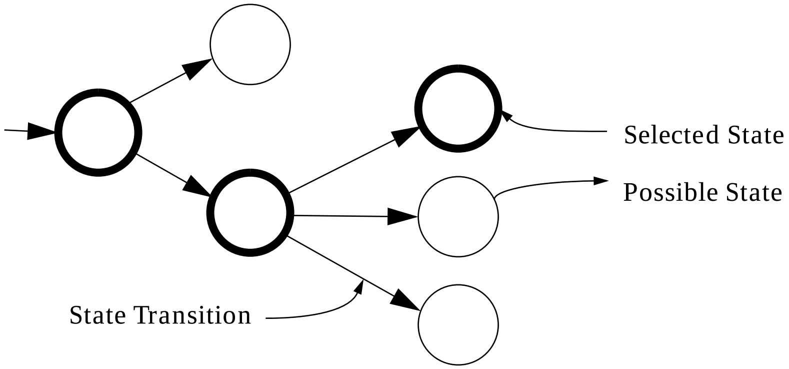
MICRO-BOSS

But What About:



Our Model of Constraint-based Scheduling

Start with state-transition model:



Transition: assertion or retraction of a "commitment" (assign value to variable, etc.)

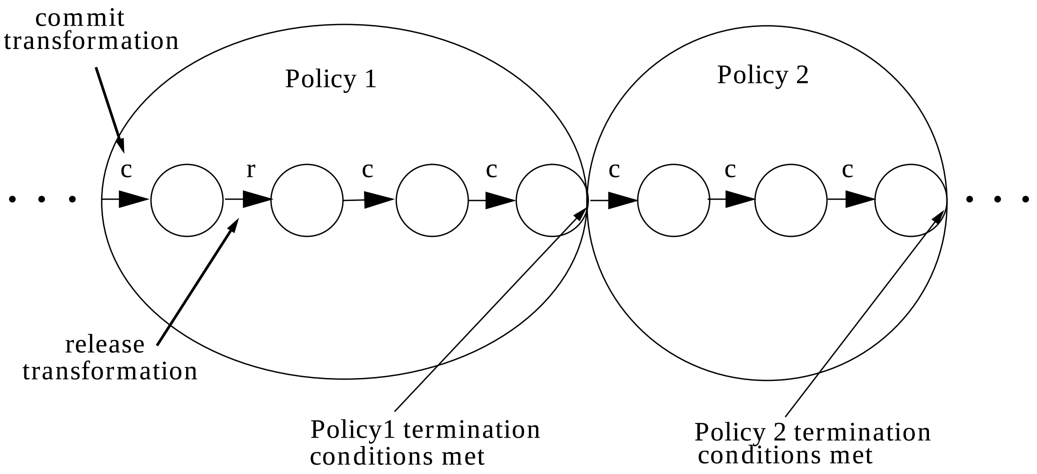
Most schedulers do not haphazardly wander through this search space. Rather, a strategy is followed for how to make commitments (and perhaps retract commitments)

Structured Commitment Transformation

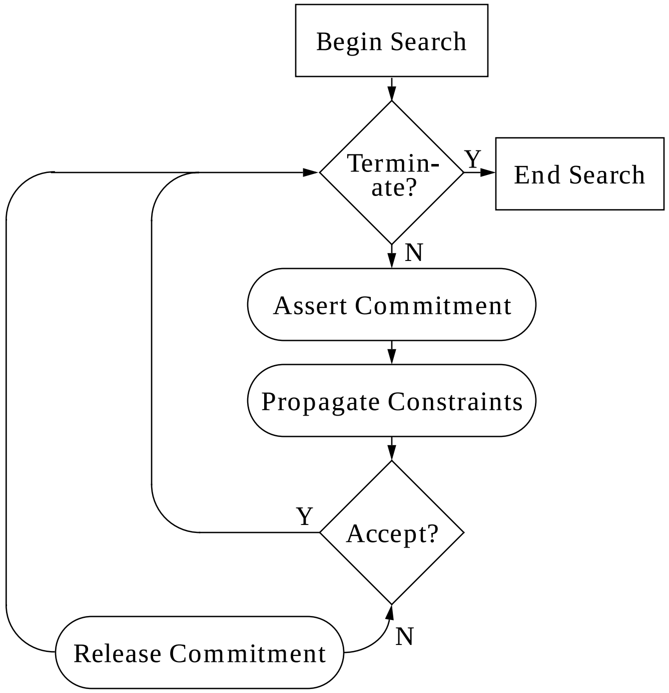
An overall strategy (“policy”) dictates how transitions are made

The strategy is followed until some termination condition occurs. At that point search can terminate or a new policy can begin

- Generalization of many observed scheduling systems
- Captures both constructive and repair-based paradigms



Overall Loop



Begin Search

Termin-ate?

Y

End Search

N

Assert Commitment

Propagate Constraints

Y

Accept?

N

Release Commitment

Texture Measurements

The problem is still deciding what type of commitment to make and what specific instance should be made at a point in the search space.

Texture measurement - a measure of the evolving constraint graph that serves as the basis for heuristic decisions.

Two main ones:

- **contention**: how much competition there is for a resource over a particular temporal interval
- **reliance**: how much an activity “needs” a resource over a temporal interval

Have extended these to deal with, *e.g.*:

- multiple and alternative resources
- changeovers
- temporal constraint posting as a commitment

ODO Time-line

Feb ’94: ODO:TOS - Eugene Davis

- unification based on commitments
- characteristics of repair vs. constructive search
- constraint relaxation - Chris Beck

Sept ’94: ODO:TNG Project begins

- architecture, representation, project management - Chris
- resource representation and reasoning - Sanket Agrawal
- texture measurements - Hong Gao

Aug ’95: Numetrix Prototype

- solving industry problems - Ioan Popescu
- logistics-level scheduling - Sanket
- reasoning about uncertainty - Hong

ODO Directions

Research driven by industrial problems from partnership with Numetrix.

- ✯ multiple and alternative resources
- ✯ dealing with changeovers (“inter-process plan constraints”)
- ✯ reasoning about (continuous) inventory
- ✯ more realistic cost model (differences between real cost and penalty cost?)
- ✯ continuous/pre-emptable activities

Research driven by the research world.

- ✯ (temporal) constraint posting as a commitment
- ✯ advanced temporal propagation [Caseau & Labuthe 95] [Carlier & Pinson 94]

Needless to say (but I will), our approach is based on texture measurements.

VELUT ARBOR ÆVO

Research Job Opening

EIL has an opening for a Research Scientist in Constraint-Directed Scheduling to work with and extend our scheduling shell, ODO.

Requirements & Details

- PhD or MSc with relevant background
- will play a leading role the design, implementation, and testing of and experimentation with future versions of ODO
- initially year (renewable for another 4)

Send email to {chris, msf}@ie.utoronto.ca.

Summary

Unifying constraint-based search with the concept of commitments.

Policy mechanism allows “shape changing”: emulation/combination of existing and future scheduling techniques.

Two general goals:

✯ direct comparison of competing scheduling technology

✯ ability to solve “real world” industry problems

Ongoing and Future Work

Using ODO as the problem solver for many of the supply chain agents (Logistics, Resource Manager, Transportation, Factory Scheduler)

Extension to a general constraint-based problem solver - beyond the scheduling world

Optimization in the real-world: using a cost model

Extensions to representation and reasoning in order to get closer to the real-world (continuous manufacturing, resource calendars, …)