Pf Problem formulation

Problem Formulation

CSE 415: Introduction to Artificial Intelligence
University of Washington
Spring, 2017

Pf Problem formulation

Outline

- Motivation
- Brief Review of Classical Problem Solving.
- Wicked Problems
  - The Climate Conundrum

Pf Problem formulation

Motivation

How do you do? Please state your problem.

--ELIZA (Joseph Weizenbaum's computer program)

- The need to solve problems never ends.
- But formulating a problem is usually a necessary first step towards solving it.

Pf Problem formulation

Problems are Getting Harder

- Global warming
- Sustainable energy production
- Weapons proliferation
- Population growth: food, sustainability
- Information glut and info. pollution
- Drug-resistant diseases

Pf Problem formulation

Problems are Getting Harder

- Global warming
- Weapons proliferation
- Population growth: food, sustainability
- Our wealth of information is getting more complex
- Diseases are resisting treatment
- Social patterns are evolving more quickly

"Wicked Problems" (Rittel & Webber, 1973)

Pf Problem formulation

Inspiration from Metamathematicians

- **G. Polya: How To Solve It** (1945) -- Deliberate Methodologies for Solving Problems

- **I. Lakatos: Proofs and Refutations** (1976) -- Interplay between problem formulation and solving.

- **S. Brown and M. Walters: The Art of Problem Posing** (2005) -- Where problems come from and how they are framed.

Current Systems with Crowdsourcing

INNOCENTIVE

koios

amazonmechanical turk
Artificial Artificial Intelligence

Missing in each: 1 or more of
Collaboration, Computation, Generality

Main Goal for Today

to deconstruct the problem formulation process

The Classical Theory of Problem Solving

- Began with the General Problem Solver (GPS) G.W. Ernst, Alan Newell & Herbert Simon.
- GPS worked by successively applying operators to try to reduce the distance from a current state to a goal state.

The CTPS is well described in several AI textbooks, e.g.,

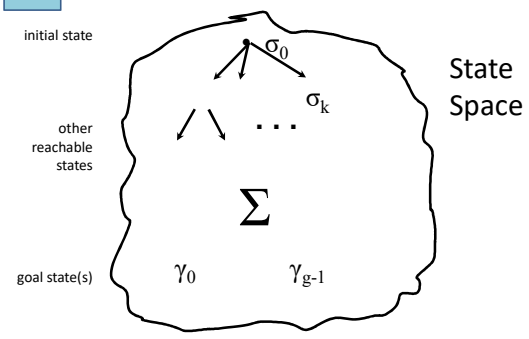
•Judea Pearl: "Heuristics: Intelligent Search Strategies for Computer Problem Solving"

•S. Russell & P. Norvig. "Artificial Intelligence: A Modern Approach"

Newell Simon Pearl

Definition

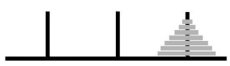
- A problem is a triple: (σ_0, Φ, Γ) where σ_0 is an initial state, Φ is a set of operators, and Γ is a set of goal states.
- Each $\varphi_i \in \Phi$ has a precondition, a state-transformation function, and an optional parameter list.
- These implicitly define Σ, the set of all states reachable from σ_0 by applying members $\varphi_i \in \Phi$ zero or more times.



Example: Towers of Hanoi

- $P = (\sigma_0, \Phi, \Gamma)$
- σ_0:

- Φ: { Move1_2, Move1_3, Move2_3, Move2_1, Move3_1, Move3_2 }
- $\Gamma = \{\gamma\}$:



Why do I use puzzles?

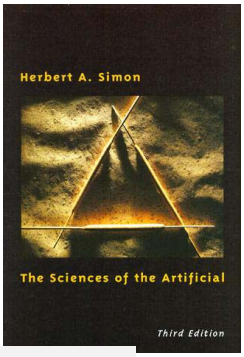
Judea Pearl:

"The expository power of puzzles and games stems from their combined richness and simplicity. If we were to use examples taken from real-life problems, it would take more than a few pages just to lay the background..."

Problem Solving = State-Space Search

Herbert Simon's Philosophy

- The classical theory applies equally well to design problems, policy problems, etc., as it does to mathematical problems.
- The "rationalist" position.



Formulation Styles

- Minimal, in numbers of state variables, operators, and/or operator options.
- Rich, with secondary state variables, redundancy in operator functionality.
- Narrow (e.g., one template per problem).
- Multi-versioned (with alternative formulations to address different interpretations of a problem)

Operator Sets: People vs Agents

- For agents: Minimal operator sets
  - avoid redundancy during exhaustive search
- For people: Rich operator sets
- For prototyping: Rich operator sets

- Strive for orthogonality, composability
- Avoid unnecessary order dependencies.

Dynamic Formulation

- Design for easy reformulation
- Support for template cloning
- Allowing solvers to address issues related to formulation --constraints
  - relaxing of constraints coded by poser
  - prioritization of "
  - addition of new constraints

Origin of "wicked problem"

attributed by Rittel and Webber to

C. West Churchman.

"Guest Editorial" of *Management Science* (Vol. 14, No. 4, December 1967)

Wicked Problems

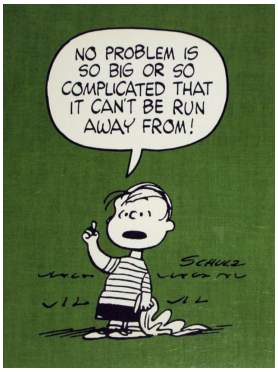
Rittel and Webber:

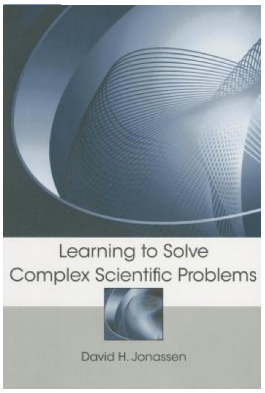
1. There is no definitive formulation of a wicked problem
2. Wicked problems have no stopping rule
3. Solutions to wicked problems are not true-or-false, but good-or-bad
4. There is no immediate and no ultimate test of a solution to a wicked problem
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly

Wicked Problems (cont.)

Rittel and Webber:

6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan
7. Every wicked problem is essentially unique
8. Every wicked problem can be considered to be a symptom of another problem
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution
10. The planner has no right to be wrong





Ill-structured problems require structuring

Why is Problem Formulation Difficult?

- Requires several kinds of knowledge.
- Some problems are "ill-structured".

Steps in Problem Formulation

- Describing a need
- Identifying resources
- Restriction and simplification
- Designing a state representation
- Designing a set of operators
- Listing constraints and desiderata
- Specifying in code the state representation, operators, constraints, evaluation criteria, and goal criterion.
- Specifying in code a state visualization method.
- If appropriate, providing for multiple roles within teams of solvers.

Steps in Problem Formulation

- Describing a need
- Identifying resources

(Preformulation)

- Restriction and simplification
- Designing a state representation
- Designing a set of operators
- Listing constraints and desiderata
- Specifying in code the state representation, operators, constraints, evaluation criteria, and goal criterion.
- Specifying in code a state visualization method.
- If appropriate, providing for multiple roles within teams of solvers.

Steps in Problem Formulation

- Describing a need
- Identifying resources

(Preformulation)

- Restriction and simplification
- Designing a state representation
- Designing a set of operators
- Listing constraints and desiderata

(Posing)

- Specifying in code the state representation, operators, constraints, evaluation criteria, and goal criterion.
- Specifying in code a state visualization method.
- If appropriate, providing for multiple roles within teams of solvers.

Steps in Problem Formulation

- Describing a need
- Identifying resources

(Preformulation)

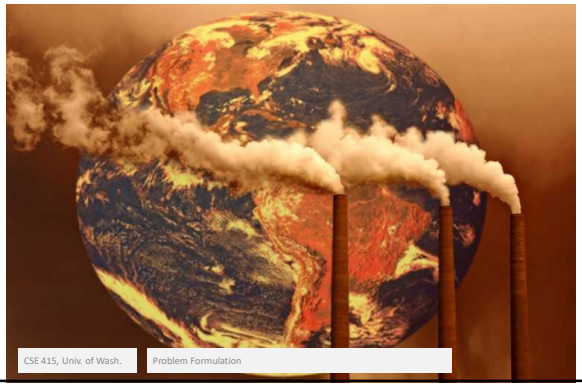
- Restriction and simplification
- Designing a state representation
- Designing a set of operators
- Listing constraints and desiderata

(Posing)

- Specifying in code the state representation, operators, constraints, evaluation criteria, and goal criterion.
- Specifying in code a state visualization method.
- If appropriate, providing for multiple roles within teams of solvers.

(Coding the formulation)

Case Study: Global Warming



Case Study: Global Warming

- "Sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
- -- *Our Common Future* (1987 report of the World Commission on Environment and Development, United Nations)

Why is the Climate Change Problem Difficult?

- Global scale
- Complexity
- Disinformation campaign
- Politics
- High costs & sacrifices required

IPCC Report of 2013

- "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased."

IPCC Report of 2013 (cont)

- "Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions."

How to Begin Understanding?

- A daunting problem, tending to overwhelm potential solvers.

- How to begin? Select key features...
- --physical model (e.g., avg. temp. aggregated over space, time)
- --a few social/artificial constructs (e.g., government programs, expected effects, costs)

Conceptual Design of a Problem Template

Design interaction affordances:

1. visualization
   --graphic
   --text
2. operators

   Presentation of the operators in natural language and figures.

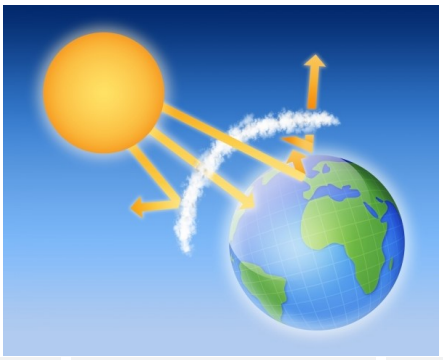
Human Value of Simplified Formulations

Counter the perception that
"This is a problem that most people just cannot get any grasp of, because it is too complex. We have no idea of what we can do that might have any effect."

Like a literary work of historical fiction, we communicate in a narrative that people can understand, that offers "cognitive handles" for grasping the key concepts involved.

Our posed problem may be a form of science fiction, but it is a step towards understanding reality because it highlights, and uses in context, the ideas needed to understand reality.

Basic Physical Model



Basic Physical Model

- Blackbody radiation equilibrium equation:
- energy absorbed = energy re-radiated

$$(1 - a)\, S\, \pi\, r^2 = 4\, \pi\, r^2\, \varepsilon\, \sigma\, T^4$$

- S: solar constant
- a: earth albedo
- ε: earth emissivity
- σ: Stefan-Bolzmann constant
- r: radius of the earth
- T: earth temperature, degrees Kelvin

Basic Physical Model

Solve for T:

$$T = \sqrt[4]{(1 - a)\, S / 4\, \varepsilon\, \sigma}$$

Earth Albedo: a

Fraction of irradiance that is reflected:

$0 \le a \le 1$

Average value:

$a \approx 0.3$

Sample albedos

Surface	Typical albedo
Fresh asphalt	0.04[2]
Worn asphalt	0.12[2]
Conifer forest (Summer)	0.08,[3] 0.09 to 0.15[4]
Deciduous trees	0.15 to 0.18[4]
Bare soil	0.17[5]
Green grass	0.25[5]
Desert sand	0.40[6]
New concrete	0.55[5]
Ocean ice	0.5–0.7[5]
Fresh snow	0.80–0.90[5]

Earth Emissivity

Emissivity is the fraction of available radiation that escapes from a body

$0 \le \varepsilon \le 1$

Average earth $\varepsilon \approx 0.6$

Increasing greenhouse gases lower it, trapping more heat.

Clouds

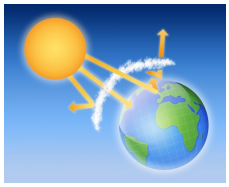
Clouds tend to block radiation:

increased albedo

decreased emissivity

Cooler days

Warmer nights



Contrails

Artificial clouds in jet wakes.

Just after 11 September 2001, flights to/from N. America stopped.

Daytime highs in N.A. were higher,

nighttime temps were lower.

Gamification of Global Warming

- Creating a challenge: survive until 2065
- Design of game operators with constraints:
  - Limited funds, interventions cost money
  - Engaging narrative

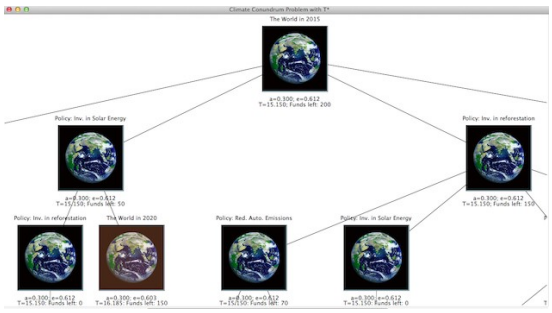
Modeling of Operator Effects

- This is perhaps the weakest scientific link in the formulation, but
- the most important in terms of engaging solvers.
- We seek:
  - SIMPLICITY (for user understanding),
  - NARRATIVE INTEGRITY (for user engagement)
  - STRUCTURAL INTEGRITY (leading to an interesting and comprehensible state space)

CLIMATE CONUNDRUM PUZZLE in TStar

- Key state variables:
  - albedo
  - emissivity
  - rate of change of emissivity
  - funds remaining
- Operators:
  - Invest in solar power
  - Invest in reducing automobile emissions
  - Invest in reforestation
  - Implement selected policies for 5 years

Portion of State Space Tree



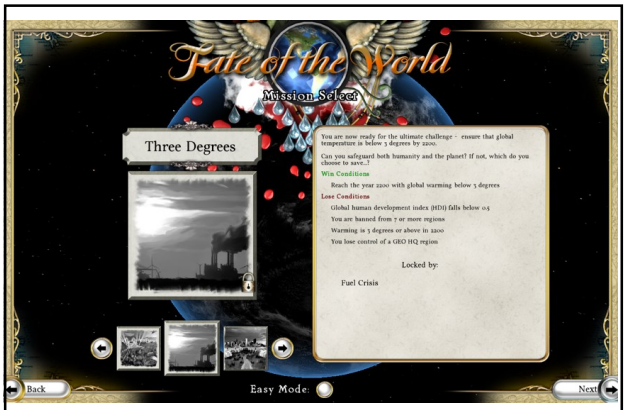
BBC Climate Challenge

- Public Broadcasting Sponsored Formulation:
- Implementation in Flash
- Main game mechanic: Selection of policy cards.

- Impact: Led to development of Fate of the World.

"Fate of the World"

- Commercial Production and Marketed successor to BBC Climate Challenge
- Simulation of earth climate, economy, politics, with regional decomposition.
- Several alternative "missions" available.
- Very difficult to win (i.e., realistic)



Climate Model for FotW

- Attributed to Oxford Univ. researcher.
- Game has thousands of parameters.
- Opaque to players.
- Parameters available via posted mods.
- Design notes available in special edition.

Some Model Parameters

```
attr={
        agriculture_coal_per_robot=0,
        agriculture_emissions_per_coal=0,
        agriculture_emissions_per_energy=0,
        agriculture_emissions_per_fuel=0.3,
        agriculture_emissions_per_gas=0.2,
        agriculture_emissions_per_transport_frght_intl=0,
        agriculture_emissions_per_transport_frght_local=0,
        agriculture_emissions_per_transport_pers_intl=0,
        agriculture_emissions_per_transport_pers_local=0,
        agriculture_emissions_per_uranium=0,
        agriculture_emissions_per_water=0,
        agriculture_emp=4.26e-07,
        agriculture_emps=0,
        agriculture_energy_per_robot=6.8e-07,
        agriculture_fuel0_per_robot=2.06e-07,
        agriculture_gas_per_robot=4.68e-07,
        agriculture_gdppw_base=1100,
        agriculture_gdppw_temp_product=1,
        agriculture_land_gdppw_mix_frac=0.55,
        agriculture_land_gdppw_weighting=0.0034,
        agriculture_livestock_gdppw_mix_frac=0.21,
        agriculture_livestock_gdppw_weighting=0.0177,
        agriculture_max_robotspw=8.3205,
        agriculture_meat_gdppw_mix_frac=0.23,
        agriculture_meat_gdppw_weighting=0.0177,
        agriculture_min_robots=6.46655e+07,
        agriculture_min_robotspw=0,
        agriculture_rregfencing_limit=1,
        agriculture_robot_growth_cell=1.03,
        agriculture_robot_reduction=1,
        agriculture_robots=6.46655e+08,
        agriculture_robots_green_frac=0,
        agriculture_sea_gdppw_mix_frac=0.01,
        agriculture_sea_gdppw_weighting=0,
        agriculture_size_ratio=0.25,
        agriculture_toxicity_per_turn=0,
        agriculture_toxicity_total=0,
```


Summary of Problem Formulation for Global Warming

- Recognize its wickedness
- Determine most important factors
- Find a simple, reliable model for some factors
- Build elements of a formulation to balance scientific accuracy, cognitive requirements, computational/design tractability.
- Allow for multiple formulations, and evolutionary development.