Metaheuristic Optimization and Local Search

Alexander G. Ororbia II
Biologically-Inspired Intelligent Systems

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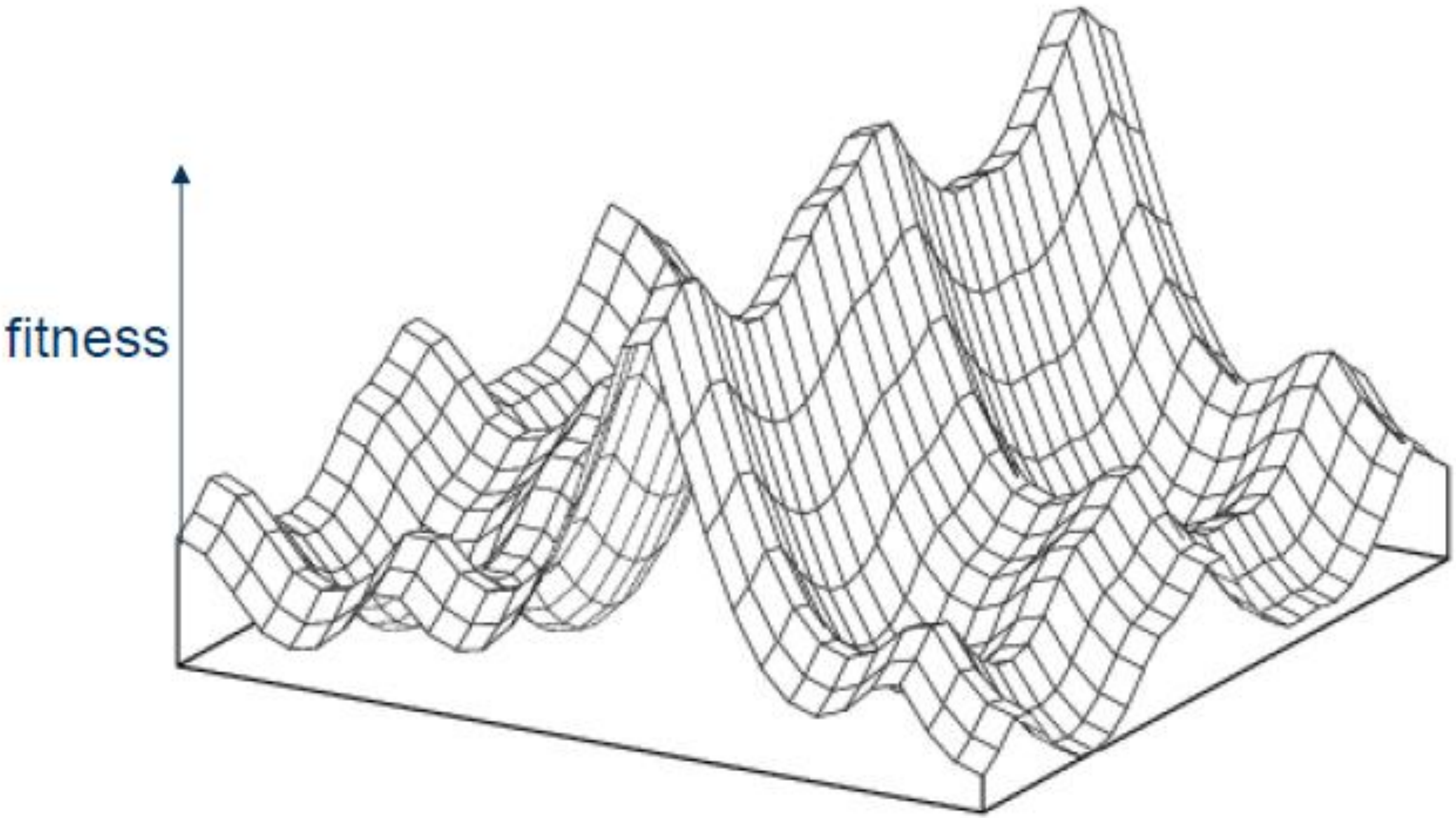
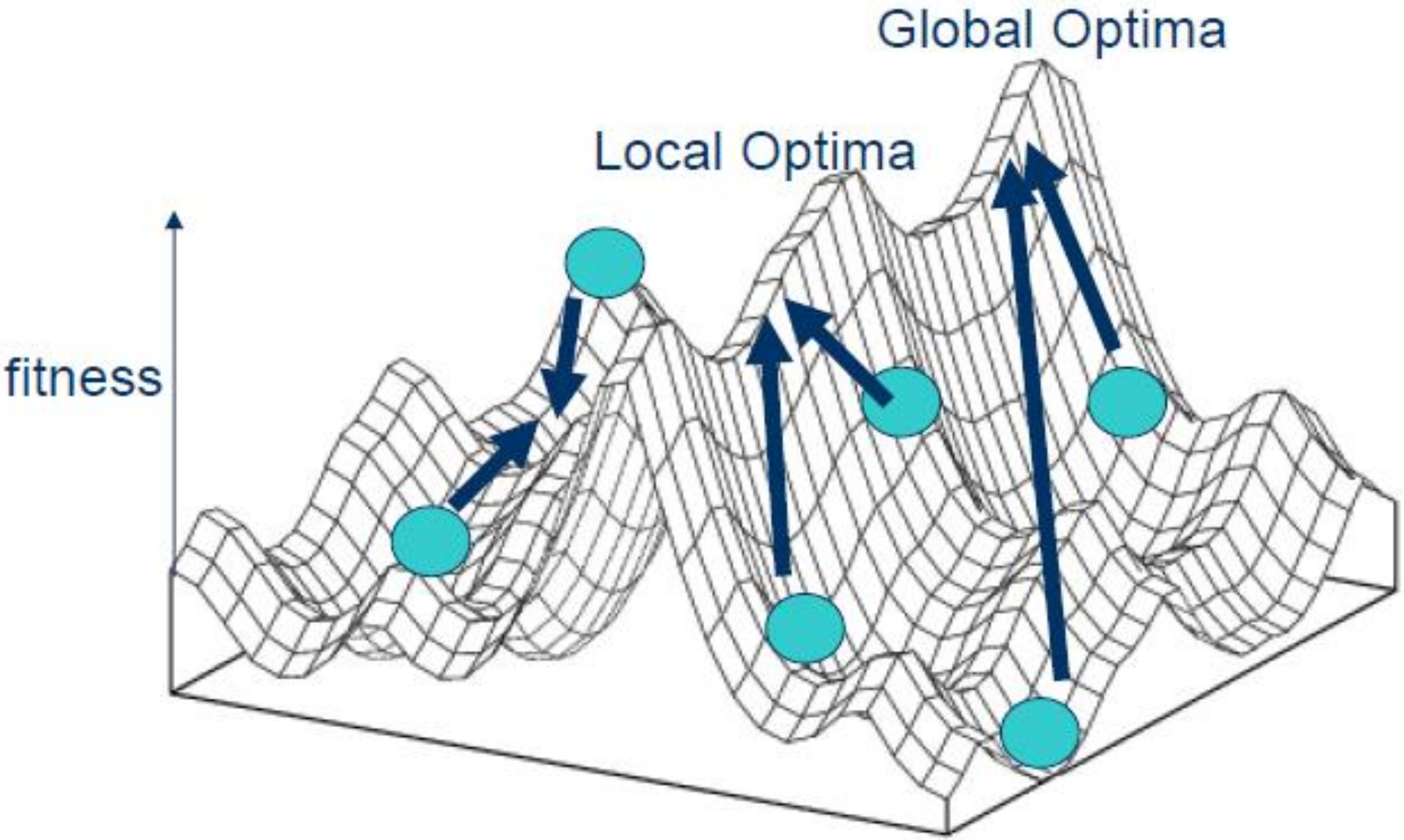
Combinatorial Problems: Fitness Landscape

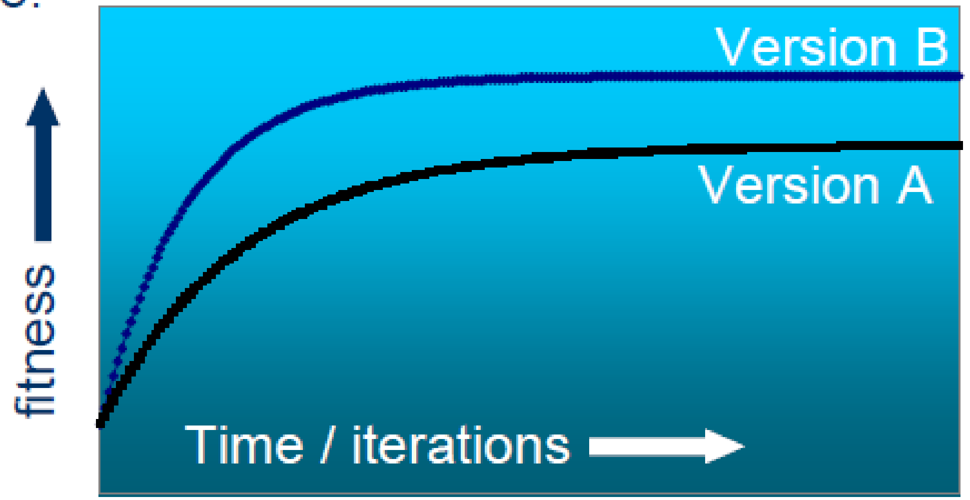


Combinatorial Problems: Fitness Landscape



Typical Behavior of an Evolutionary Algorithm

- As the population evolves, the quality of the solutions in the population tends to increase.



- Typically, the performance of the EA will be affected by choice of:
  - Parameter Settings (Population size, mutation rate, etc.)
  - Types of operators, population policies used etc.

  Unfortunately, this is somewhat of a "black art"

Ant Colony Optimization

- Another important metaheuristic

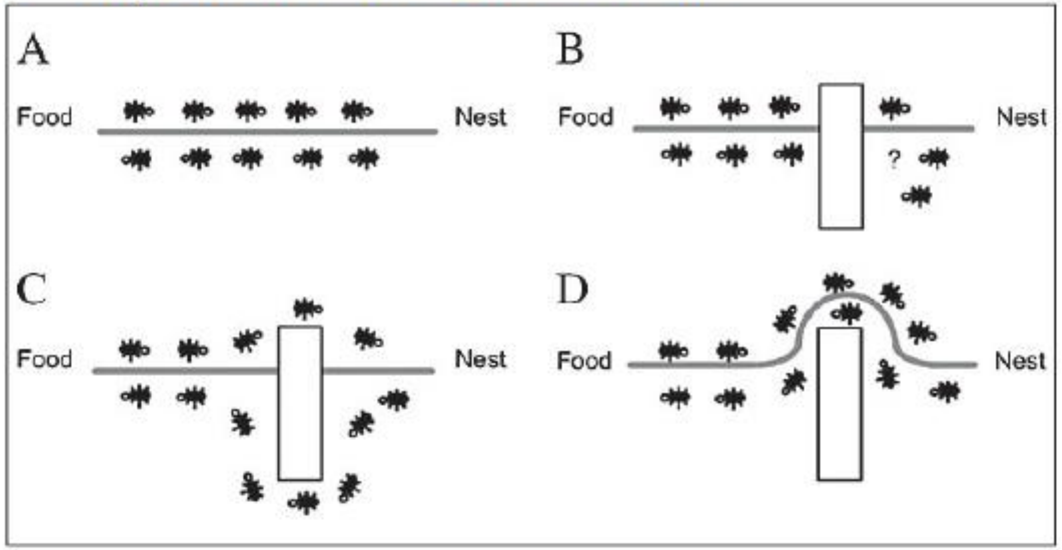


Figure 2. A. Ants in a pheromone trail between nest and food; **B.** an obstacle interrupts the trail; **C.** ants find two paths to go around the obstacle; **D.** a new pheromone trail is formed along the shorter path.

- Like evolutionary algorithms, ACO is applicable to a wide range of problems

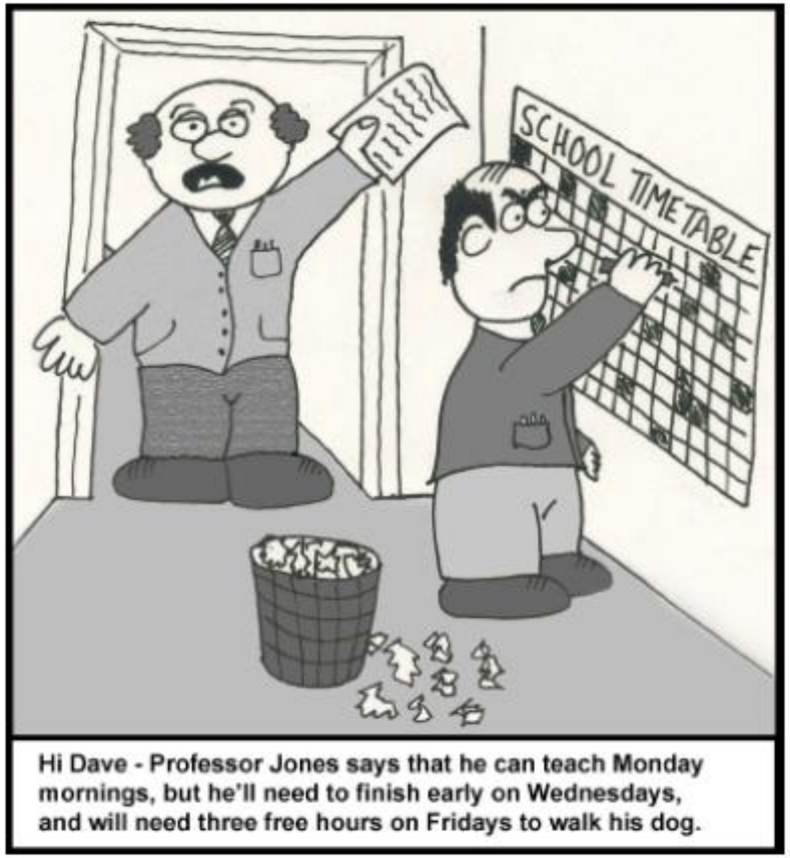
History of Metaheuristics

- 1965: first evolution strategy (Hans-Paul Schwefel)
- 1975: first genetic algorithm(s) (Turing -1954, Alex Fraser)
- 1983: simulated annealing (Pincus 1970 & many others independently)
- 1986: tabu search (Fred Glover)
  - Takes potential soln & checks immediate neighbors (differ by minor details)
  - Worsening moves accepted, “prohibitions” prevent revisiting old soln’s
  - If soln w/in short period of time or violates rule, marked as “tabu”
- 1991: ant colony optimization (Pierre-Paul Grasse)
- 1997: variable neighborhood search (Mladenovic & Hasen)
  - Descent to local optimum, then perturb to get out of valleys
- 2000+: parallel and distributed computing in metaheuristics

Questions in Metaheuristic Research

- Research questions include:
  - What quality of solutions can we expect from our algorithm?
  - How fast is the algorithm?
  - How do the solutions / run-times compare to other methods?
  - How robust/reliable is the algorithm?
  - Is the algorithm more reliable with certain types of problem instances (e.g. those of a certain size)?
- Such questions are usually answered empirically

Another Application: University Timetabling



- A problem common to all universities
- Assign “events” to timeslots and rooms while obeying various constraints
- Typically constraints for this problem are idiosyncratic (every university is different)
- Research in the field typically disconnected

International Timetabling Competition (ITC)

- `www.cs.qub.ac.uk/itc2007/`
- Run between August ’07 and January ’08
- **Idea:** Design the best algorithm for a number of benchmark problem instances.
- Three competition tracks – exam timetabling, curriculum-based timetabling, and post enrolment-based timetabling
- Any type of algorithm was permitted, including commercial software.
- A strict run time limit imposed (approx 5 min. depending on machine and platform)
- Performance judged on solution quality *at the time limit*
- Algorithms were ranked against one another, and performance was verified on the organisers computers

Timetabling Competition: *ITC2007*

- Example: Post enrollment-based course timetabling (track 2)

- Assign each event to a room and timeslot such that:
  - No student or room is double-booked
  - Precedence constraints are obeyed
  - All events occur in *suitable* rooms
- Soft Constraints are also considered, such as:
  - Students should not have to sit three lectures in a row
  - Students should not have a lecture in the 5pm timeslot
  - Students should not have just one lecture in a day

Timetabling Competition: *ITC2007*

- Over 40 entrants from across the globe
- All finalists in each track used metaheuristic-based approaches

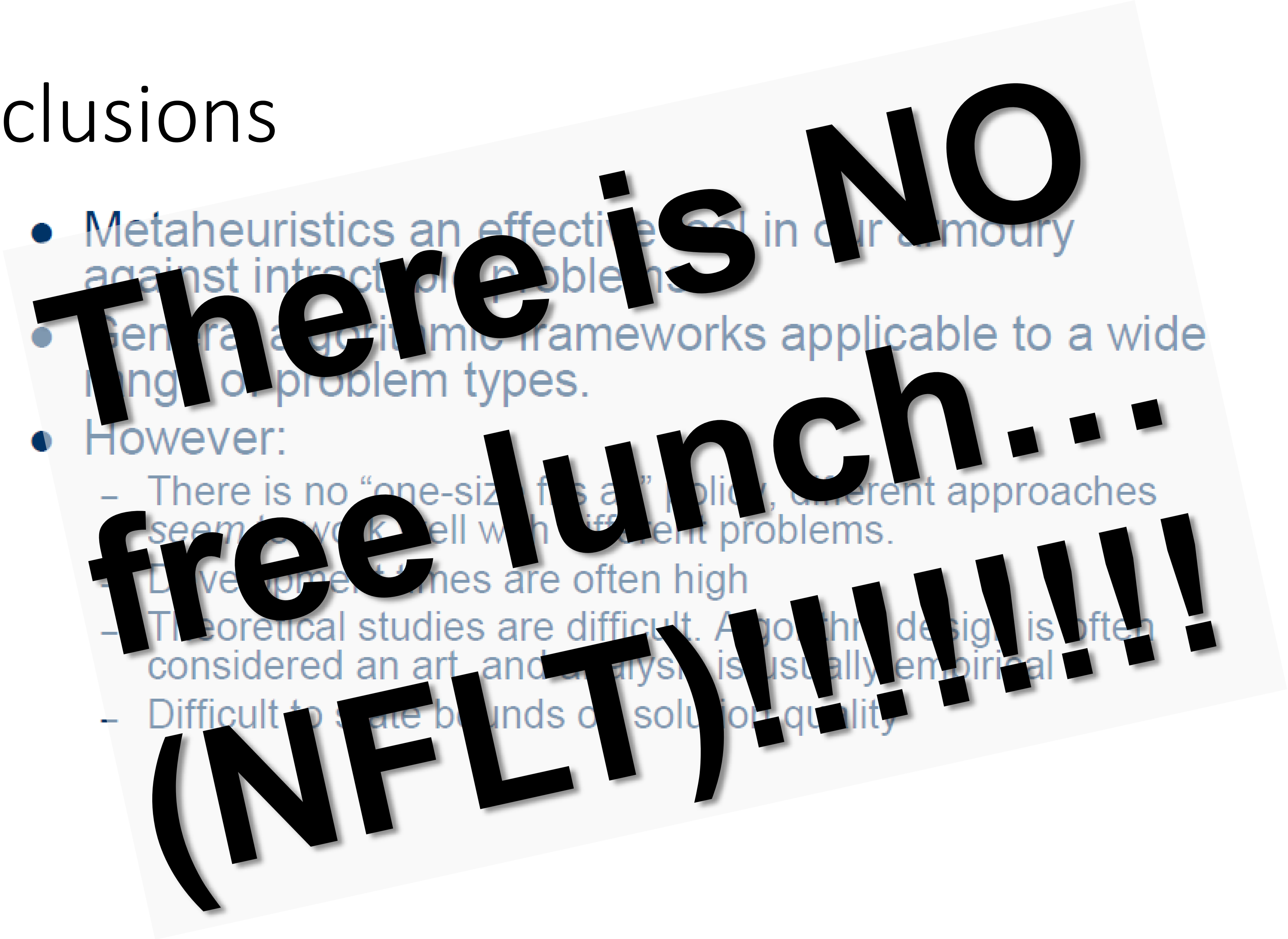
Results of Track 2

Rank	Entrants	Affiliation
(1)	Hadrien Cambazard, Emmanue Hebrard, Barry O'Sullivan, and Alexandre Papadopoulos	Cork Constraint Computation Centre, **Ireland**
(2)	Mitsunori Atsuta, Koji Nonobe, and Toshihide Ibaraki	Kwansei-Gakuin University, **Japan**
(3)	Marco Chiarandini, Chris Fawcett, and Holger Hoos	University of Southern **Denmark**
(4)	Clemens Nothegger, Alfred Mayer, Andreas Chwatal, and Gunther Raidl	Vienna University of Technology, **Austria**
(5)	Tomas Müller	Purdue University, **USA**

The Metaheuristic "Toolbox"

- Metaheuristics an effective tool in our armoury against intractable problems
- General algorithmic frameworks applicable to a wide range of problem types
- However:
  - There is no "one-size fits all" policy, different approaches *seem* to work well with different problems
  - Development times are often high
  - Theoretical studies are difficult. Algorithm design is often considered an art, and analysis is usually empirical
  - Difficult to state bounds on solution quality

Conclusions



Questions?