Topic 18: Conclusion
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Course 1DL441:
Combinatorial Optimisation and Constraint Programming,
whose part 1 is Course 1DL451:
Modelling for Combinatorial Optimisation

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Outline

1. Constraint Problems

2. Constraint Programming Technology

3. Constraint-Based Modelling

4. History & Success Stories & Opportunities

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Outline

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Many important real-life problems are NP-hard or worse and can only be solved exactly & fast enough by intelligent search, unless P = NP:

- Personnel rostering, scheduling, time-tabling, ...
- Transportation logistics: vehicle routing, ...
- Packing: container or truck loading, carpet cutting, ...
- Configuration, design, experiment set-up, ...
- Alignment of bio-molecules, phylogeny, ...
- Financial investment instrument design, ...
- ...

Definition

In a constraint problem, values have to be **found** for all the variables within their **given** domains so that:

- All the given constraints on the variables are **satisfied**.
- Optionally: A cost is **minimal**, or a benefit is **maximal**.

Search spaces are often larger than the universe!
NP-hardness is not where the fun ends, but where it begins!

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Constraint programming (CP) offers methods & tools for:

what: Modelling constraint problems in a high-level language.

how: **Solving** constraint problems intelligently,
by strategy-guided systematic search plus inference, or
by (meta-)heuristic-guided local search plus inference.

Slogan of CP:

Constraint Program = Model [+ Search]

CP solvers are complementary in strength to those of:

- Operations Research (OR): linear programming (LP), integer LP (ILP), mixed integer programming (MIP), ...
- Boolean satisfiability (SAT), modulo theories (SMT)
- ...

This leads to hybrid optimisation technologies!

☞ In my Algorithms and Data Structures 3 (1DL481), taught in period 3 (January to March), there are assignments on local search as well as on MIP, SAT, and SMT modelling.

Scope of Constraint Programming

CP has a wide scope, as it addresses:

- satisfaction problems and optimisation problems
- discrete variables and continuous variables
- linear constraints and non-linear constraints

in principle in any combinations thereof, by:

- systematic search, if optimality more crucial than speed
- local search, if speed is more crucial than optimality

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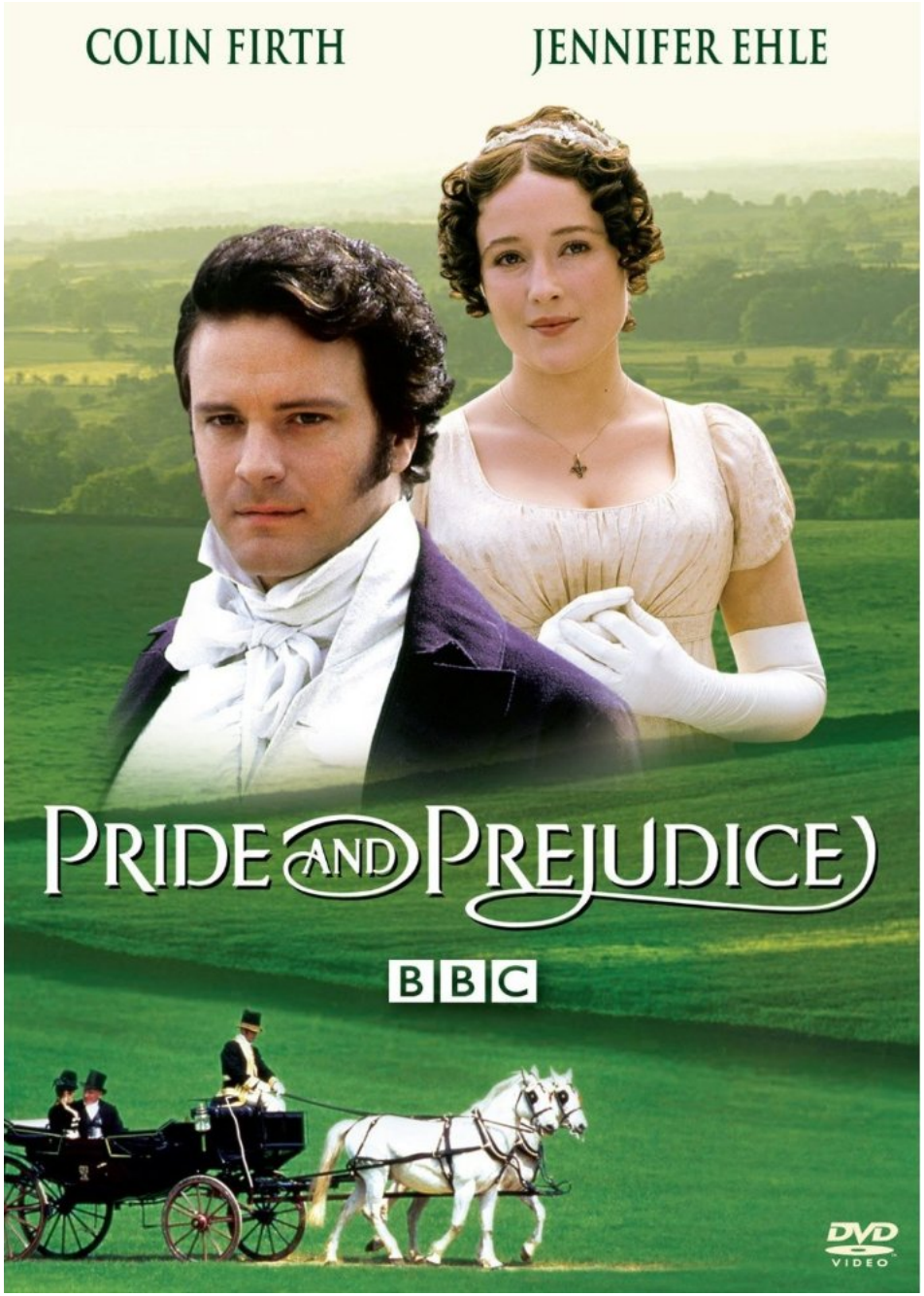
The constraint predicates (`circuit`, `extensional`, `distinct`, ...) and structured variable types (sets, ...) allow us both to model the structure of a constraint problem and to exploit that structure when solving it.

Dozens of constraint predicates (see the Catalogue) declaratively encapsulate complex inference algorithms.

There is no standardised CP modelling language: distinct CP solvers may support distinct predicates, possibly under distinct names and signatures, as well as distinct types.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Pride:

Constraint programming represents one of the closest approaches computer science has yet made to the Holy Grail of programming: the user states the problem, the computer solves it.

— Eugene Freuder, a CP pioneer

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Prejudice:

The contribution of the article should be the reduction of an engineering problem to a known optimization format. [. . .] showcases pseudo code [. . .] submit this work to a journal interested in code semantics [. . .].

— Reviewer of a paper of ours at a prestigious OR journal

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Stand-alone languages:

- ALICE by Jean-Louis Laurière, France, 1976
- CHIP at ECRC, Germany, 1987 – 1990, then marketed by Cosytec, France
- OPL, by P. Van Hentenryck, USA, and ILOG, France: front-end to both ILOG CP Optimizer and ILOG CPLEX
- Comet, by P. Van Hentenryck and L. Michel, USA
- MiniZinc, at U. of Melbourne and Monash U., Australia
- . . .

Libraries (the ones listed before ";" are open-source):

- Prolog: ECLiPSe, . . . ; SICStus Prolog, . . .
- C++: Gecode, OR-Tools; IBM CP Optimizer, CHIP, . . .
- Java: Choco, Google OR-Tools, JaCoP, MiniCP, ...; . . .
- Scala: OscaR; . . .
- . . .

Success Stories by CP Users and Contributors:

Success stories: CP = **technology of choice** in scheduling, configuration, personnel rostering, timetabling, . . .

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Opportunities for CP

Rapid prototyping (with high solving performance) when:

- Constraints are, still or again, subject to experiments
- Partition into hard & soft constraints yet undetermined

Combinatorial structure is impure, due to side constraints.

It is time to consider all or more problem constraints.

Domain knowledge exploitable for problem-specific search.

It is a configuration problem.

It is a personnel rostering problem.

It is a scheduling problem.

It is a time-tabling problem.