Why ESSENCE?

Frequently Asked Questions about a New Language for Specifying Combinatorial Problems

Alan M. Frisch (Univ. of York)

Matthew Grum (Univ. of York)

Christopher Jefferson (Oxford Univ.)

Bernadette Martinez Hernandez (Univ. of York)

Ian Miguel (Univ. of St. Andrews)

ESSENCE FAQ: The dream

Why is your product so vastly superior in all respects to those of your competitors?

ESSENCE FAQ: The reality

Why the hell are you wasting your time on this?

Outline

- What is ESSENCE?
- What motivated you to design ESSENCE?
- What were the objectives in designing ESSENCE?
- Questions from the audience:
  - 11 others from the paper
  - Any of your own

Question 1

What is ESSENCE?

ESSENCE is …

- A language for specifying combinatorial *problems*.
- Natural:
  - Enables formal specifications similar to the rigorous ones that people give using a mixture of natural language and discrete mathematics (e.g., Garey and Johnson).
  - Intended to be accessible to anyone with a background in discrete mathematics (not constraint programming).

ESSENCE is …

- Not a logical langauge such as Z or NP-SPEC.
- Similar to OPL, F or ESRA enhanced with features that greatly enhance its level of abstractness
  - Since combinatorial problems require finding a certain type of combinatorial object, ESSENCE provides decision variables whose domains are objects of that type.
  - This enables problems to be stated directly, *without modelling* the decision variable as a collection of simpler decision variables.

Is ESSENCE Natural?

ESSENCE

given U enum(…), s, v: U→int (1…), B, K: int (1…)

find U ': set of U

such that $\sum_{u \in U'} s(u) \leq B$, $\sum_{u \in U'} v(u) \geq K$

Garey and Johnson

INSTANCE: Finite set U, for each u in U: a size $s(u) \in Z^+$, a value $v(u) \in Z,^+$ and positive integers B and K.

QUESTION: Is there a subset $U' \subseteq U$ such that $\sum_{u \in U'} s(u) \leq B$ and $\sum_{u \in U'} v(u) \geq K$

The SONET Problem

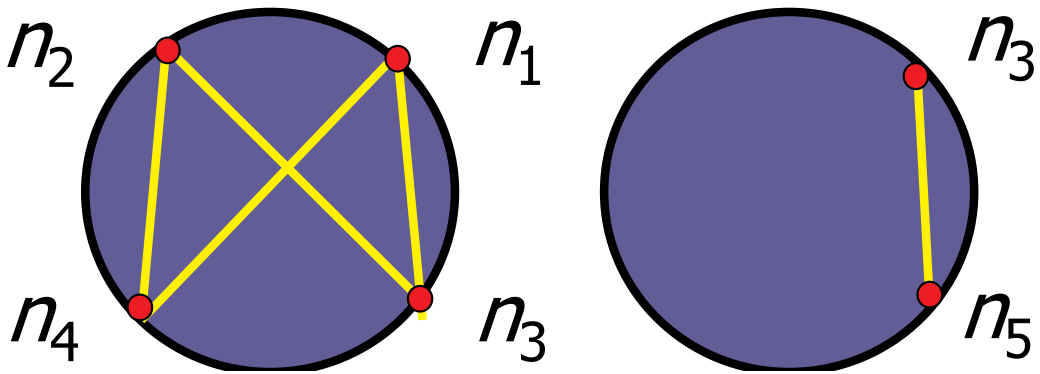
Specification

- Given ***nrings*** rings, ***nnodes*** nodes, a set of pairs of nodes (communication ***demand***) and an integer ***capacity*** (of each ring). Install nodes on rings satisfying demand and capacity constraints. Minimise installations.

Instance

- *nrings*=2, *nnodes*=5, *capacity* = 4
- *demand*: n_1 & n_3, n_1 & n_4, n_2 & n_3, n_2 & n_4, n_3 & n_5

Solution



SONET Specification

given *nrings*, *nnodes*, *capacity* : int (1…),
demand : set of set (size 2) of int (1..*nnodes*)

find *network* : mset (size *nrings*) of set (maxsize *capacity*)
of int (1..*nnodes*)

minimising $\sum_{ring \in network} . |ring|$

such that $\forall_{pair \in demand} . \exists_{ring \in network} . pair \subseteq ring$

ESSENCE Provides Abstract Types

Atomic: int, bool, enum, unnamed
Constructors: sets, multisets, partitions, functions, relations, tuples

Abstract types

given *nrings*, *nnodes*, *capacity* : int (1...),
demand : set of set (size 2) of int (1..*nnodes*)

find *network* : mset (size *nrings*) of set (maxsize *capacity*)
of int (1..*nnodes*)

minimising $\sum_{ring \in network} . |ring|$

such that $\forall_{pair \in demand} . \exists_{ring \in network} . pair \subseteq ring$

ESSENCE Supports Arbitrarily-Nested Types

Arbitrary nesting of types

given *nrings*, *nnodes*, *capacity* : int (1…),
demand : set of set (size 2) of int (1..*nnodes*)

find *network* : mset (size *nrings*) of set (maxsize *capacity*)
of int (1..*nnodes*)

minimising $\sum_{ring \in network} . |ring|$

such that $\forall_{pair \in demand} . \exists_{ring \in network} . pair \subseteq ring$

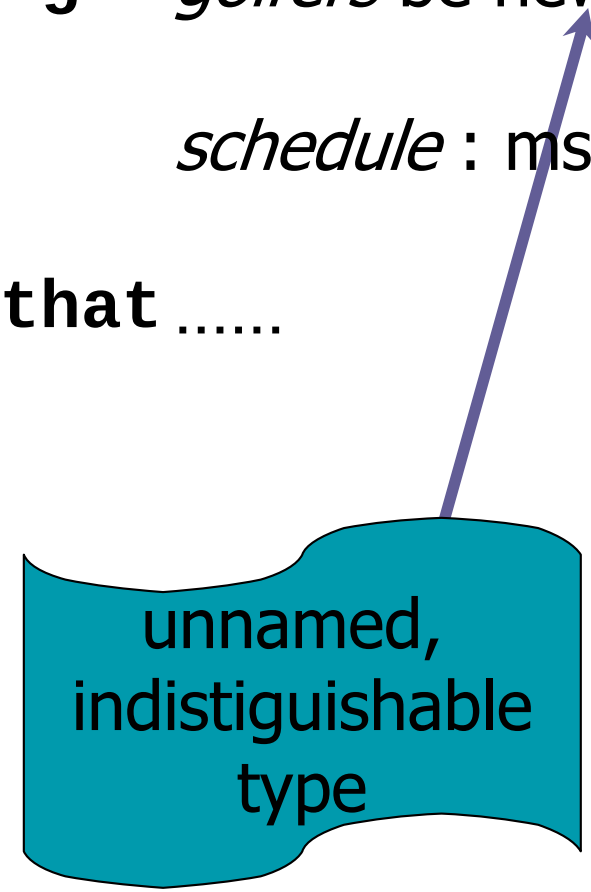
ESSENCE Unnamed, Indistinguishable Types

given *w, g, s* : int (1…)

letting *golfers* be new type of size *g*s*

find *schedule* : mset (size *w*) of rpartition (size *s*) of *golfers*

such that ……



ESSENCE Supports Quantification over Decision Variables

given *nrings, nnodes, capacity* : int (1…),
demand: set of set (size 2) of int (1..*nnodes*)

find *network*: mset (size *nrings*) of set (maxsize *capacity*)
of int (1..*nnodes*)

minimising $\Sigma_{ring \in network} . |r|$

such that $\forall_{pair \in demand} . \exists_{ring \in network} . pair \subseteq ring$

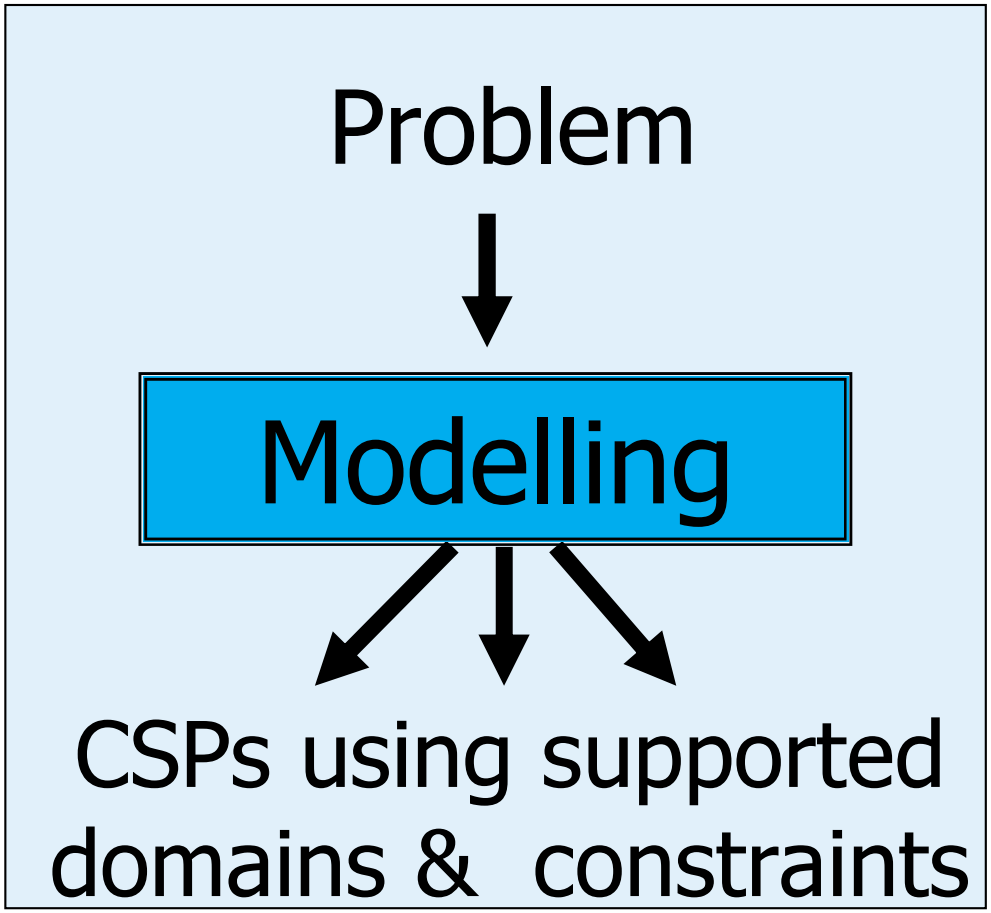
Quantifying Over Decision Variables

Question 2

What Motivated You to Design ESSENCE?

Motivation 1: Automated Modelling

What is modelling?

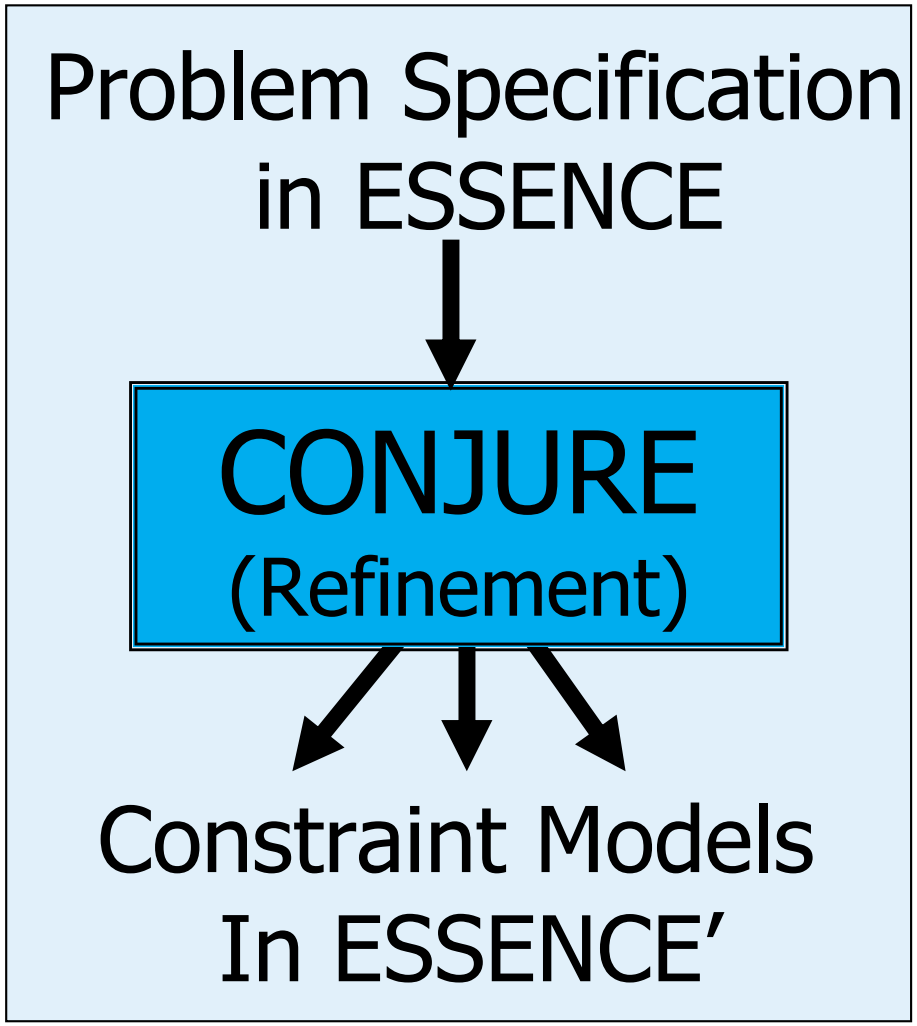


Usually unsystematic – an art

Social Golfers Problem requires finding a multiset of partitions.

At least 72 ways to model this with a set of atomic or atomic set variables

Motivation 1: Automated Modelling



- Input spec must be sufficiently abstract so that no modelling decisions have been made in constructing it
- Thus, spec language provide level of abstraction above that at which modelling decisions are made
- Having such a *problem specification language* is a prerequisite to studying automated modelling

Motivation 2: Human Communication

- Formal problem specifications could facilitate communication between humans better than the informal ones currently used.
  - Example: Could be used in CSPLib.
  - Requires availability of problem specificaiton language

Question 3

What Were the Objectives in Designing ESSENCE?

Objective 1: Naturalness

- Necessary for human communication
- Necessary for input to automated modelling system
  - One cannot claim to have an automated modelling system if using it requires a major translation into the system's input language.

Objective 2: Abstractness

- Necessary for input of automated modelling system
- Necessary to obtain naturalness

Objective 3: Capture CSP

- All problems specified in the language must be reducible to finite-domain CSP.
  - Example: syntax ensures that every decision variable has a *finite* domain. Bounds of a matrix cannot be a decision variable.

Further Questions

- What evidence is there that you have met the design objectives?
- There already exist many specification languages, most notably Z. Do we really need another one?
- ESSENCE appears to provide some redundant type constructors. Why?
- ESSENCE appears to be missing type constructors for some important combinatorial objects. It also appears to be missing some of my favourite operators. Why?
- Why does ESSENCE provide a `maxsize` annotation but no minsize annotation?
- Why is it so important to avoid introducing symmetry into problem specs?
- What is the current status of ESSENCE?
- What do ESSENCE an ESSENCE' have to do with automated modelling?
- What progress have you made towards the automation of modelling?
- What are your plans for future work

Further, Further Questions

- Though ESSENCE has been shown to be useful in specifying a wide range of problems, how do we know that you haven’t selected the problems based on their ease of specification?

Question 10

Why is it so important to avoid introducing symmetry into problem specifications?

Sources of Symmetry in Constraint Models

- Inherent in problem
  - E.g. rotation of chess board in n-queens
- In modelling
  - Since modelling languages often force a spec to
    - Introduce unnecessary objects
    - Unnecessarily distinguish between objects
  - Example: Social Golfers Problem

Sufficient Facilities for Abstraction?

- Never force introduction of unnecessary objects or distinctions
- Guiding principle in design of ESSENCE
- Elimination of symmetry has been used to evaluate ESSENCE
  - Every problem we have considered has an ESSENCE spec that contains no symmetries other than those inherent in problem.
  - No other language meets this test

Important Consequence

- All non-inherent symmetries in a model have been introduced by modelling process
- Hypothesis: Modelling is systematic and symmetries are introduced in a systematic way.
  - An automated modelling system ought to be able to identify the symmetries it has introduced
  - CONJURE prototype does it!

Question 11

What is the current status of ESSENCE?

Status of ESSENCE

- Full definition of Version 1.1.0
  - Syntax and semantics
- Haskell implementation of parser complete
  - Type checking, type inference, category checking
- Java implementation of parser nearing completion
- ESSENCE' 1.b.a (subset of Essence 1.1.0)
  - Solver-independent modelling language (OPL-like)
  - Translator to Eclipse is implemented
  - Translator to Minion under development

How Usable is ESSENCE?

- Specifications of ~50 problems found in the CSP literature written by an undergraduate with **no** background in constraint programming.

- URL: http://www.cs.york.ac.uk/aig/constraints/

Further Information

- http://www.cs.york.ac.uk/aig/constraints/
  - Our papers
  - Catalogue of CONJURE rules
  - Syntax and semantics of ESSENCE version 1
  - Catalogue of ~50 problems specified in ESSENCE and other constraint languages