Scene Interpretation as Configuration

Scene Interpretation as a Configuration Problem

What is a configuration problem?

Construct an aggregate (a configuration) given

- **generic descriptions of parts**
- **compatibility constraints between parts**
- **a concrete task description**

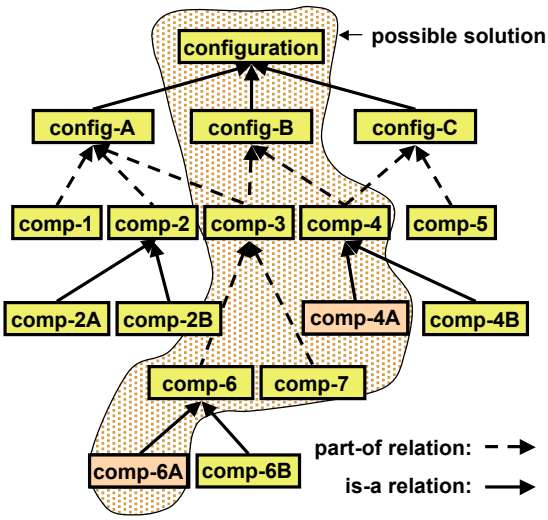
Scene interpretation may be viewed as constructing a "scene aggregate" which

- **meets generic constraints and**
- **incorporates parts prescribed by the concrete task**

Both, scene interpretation and configuration, can be described as logical model construction.

Methods and tools of configuration technology may be exploited

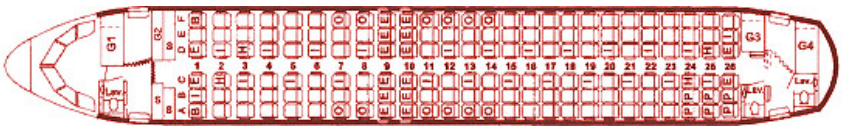
Illustration of Configuration



- boxes (frames) specify aggregate and component properties
- has-part relations bind components to aggregates
- is-a relations describe variants of entities
- constraints between entities (not shown) restrict choices and parameter combinations

Animated slide!

A Real Configuration Task



Placement of cabin equipment (seats, kitchens, toilets, etc.) in view of

- customer wishes
- technical constraints
- legal constraints
- optimality criteria

Example of Concept Definition in KONWERK

KONWERK is a configuration system prototype developed at the AI Lab (LKI) of Hamburg University in 1986 - 1994. The commercial system Engcon has been developed based on KONWERK.

M. Kopisch, A. Günter: Configuration of a Passenger Aircraft Cabin based on Conceptual Hierarchy, Constraints and flexible Control
In: 5. IEA/AIE, Springer, 1992 und 6. Workshop Planen und Konfigurieren, München

Concept "galley" describes service station in Airbus A340

```
def-concept
   :name galley
   :super-concept {cabin-interior-component rectangle}
   :parameters
        ref-nr [integer 2531000 2533999]
        door {1 2 4}
        trolleys {0 2 3 4 5 6 7 8 9 10}
        half-size-trolleys {0 1 2 3 4 5}
        meals [integer 28 140]
        type {longitudinal transversal}
        height {full half} (default 'full)
   :relations
        part-of [passenger-class]
```

Object Descriptors

Object descriptors define object classes (concepts) by specifying possible instances (compare with concept expressions in a DL).

Specific values:	**red, 35t, car37**
Choice sets:	**{red yellow green black blue}**
Intervals:	**[10km/h 300km/h]**
Predicates:	**(:satifies evenp)**
Concepts:	**(a car)**
	(a chassis (axle_load [10t 40t]))
Atomic concepts:	**(a symbol (self {red yellow green black blue}))**
	(a number (self [0 inf]))
Logical operators:	**(:and [50 100] (:satisfies evenp))**

Set Descriptors

Set: (:set (a motor) (a body) (a chassis))

short form for

```
(:set   #[(a car_part) 3 3]
        #[(a motor) 1 1]
        #[(a body) 1 1]
        #[(a chassis) 1 1])
```

Subset: (:some (a motor) 2 4) ≈ #[(a motor) 2 4]

Decomposition Relations

```
(is   (a car)
      (an object
            (has-parts   (:set   (a motor)
                                 (a body)
                                 (a chassis)))))

(is   (a car)
      (an object
            (has-motor          (a motor)
            (has-body           (a body)
            (has-chassis        (a chassis)))))
```

Example: Concept for Building Recognition

Concept definition for the aggregate "wall"

```
(def-do    :name Wall
 :oberkonzept Scene-Part
 :relationen ((has-elements (:spezialisierte-menge
                 (:einige (ein Image-Object) :min 0 :max inf)
                 :spezialisierungstyp :=
                 :spezialisierung
                 #[(ein Balcony) 0 inf]
                 #[(ein Window) 0 inf]
                 #[(ein Gate) 0 inf]
                 #[(ein Entrance) 0 inf]))
          (element-of
               (:spezialisierte-menge
                 (:einige (ein Scene-Part) :min 1 :max 1)
                 :spezialisierungstyp :>
                 :spezialisierung
                 #[(ein Building) 0 1]
                 #[(ein Entrance) 0 1]
                 #[(ein Balcony) 0 1])))))
```

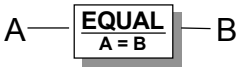
Representation Language of KONWERK

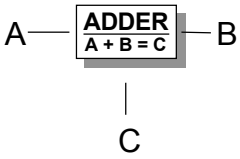
Language constructs can be mapped to logical constructs of a description logic by using:

- **Conjunction**
- **Negation and disjunction with atomic concepts**
- **Value restrictions**
- **Qualifying number restrictions**
- **Inverse roles**
- **Sets**
- **Concrete domains over R**

Constraint-based Configuration

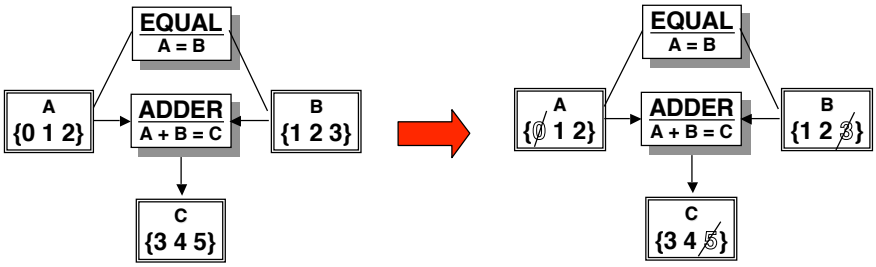
- Constraints represent **relations** between parameters or concepts
- Constraints are **multi-directional**
- Generating a constraint **network** (system of equations)
- **Consistency** check for value settings
- Restricting value ranges by **propagation**
- Computing all **solutions** by using constraint-satisfaction technologies
- **Incrementally increasing** constraint net





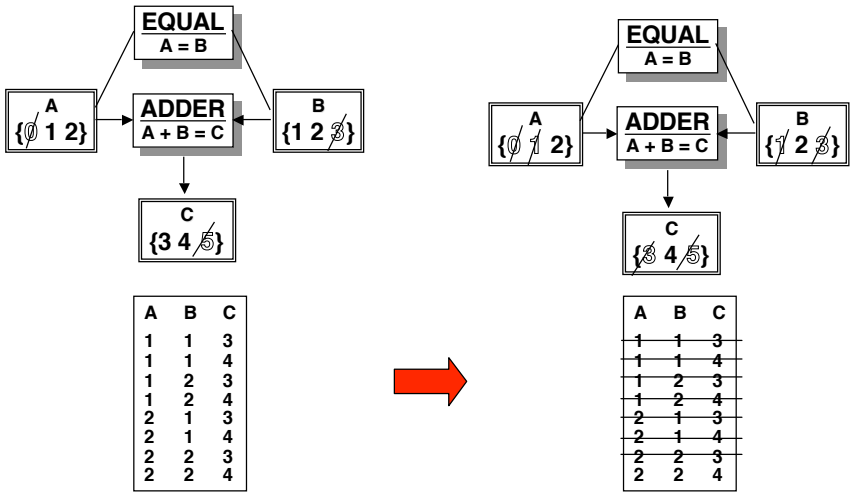
Constraint Propagation (1)

KONWERK supports
constraint propagation for local consistency



Constraint Propagation (2)

KONWERK also supports constraint propagation for global consistency



Constraints in KONWERK

- **Constraint classes**
  Predominantly domain-independent computational procedures
  Examples: adder, multiplier, sum, equal
- **Conceptual constraints**
  Description of a domain-specific constraint type, instantiation rules
  Example: motor displacement = sum of cylinder displacements
- **Constraint instances**
  Dynamically generated at configuration time
- **Constraint net**
  Propagates values through all constraint instances, recognizes conflicts

Example: Constraint for Building Recognition

Constraint ensures that the bounding-boxes of parts of a wall are contained in the bounding-box of a wall.

```
(def-konzeptuelles-constraint
 :name All-Parts-of-Wall-are-in-Wall
 :variablen-pattern-paare (
              (?w :name Wall)
              (?p :name Image-Object
              :relationen ((element-of
                        (:globale-bedingung
                     '(is-in-set ?w *it*))))))
 :constraint-aufrufe ((bb-inside-fuzzy (?w 'Pos-X-1) (?p 'Pos-X-1)
                   (?w 'Pos-Y-1) (?p 'Pos-Y-1)
                   (?w 'Pos-X-2) (?p 'Pos-X-2)
                   (?w 'Pos-Y-2) (?p 'Pos-Y-2))))
```

Central Configuration Cycle

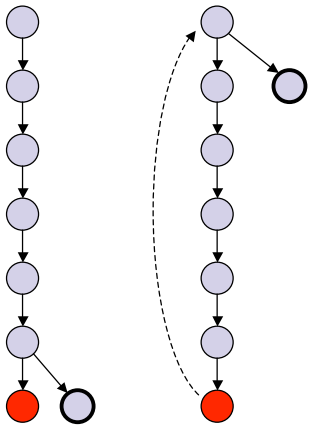
Repeat
- **Check for goal completion**
- **Determine current strategy**
- **Determine possible configuration steps**
- **Select from agenda and execute one of**
  - **{ aggregate instantiation,**
  - **aggregate expansion,**
  - **instance specialisation,**
  - **parameterisation,**
  - **instance merging }**
- **Propagate constraints**
- **Check for conflict**

For value selection one can use

- **default value assignment**
- **computational procedure**
- **user interaction**
- **library solution**
- **local breadth-first search**

Backtracking

In case of a conflict, backtracking occurs. One may select one of 3 backtracking strategies:



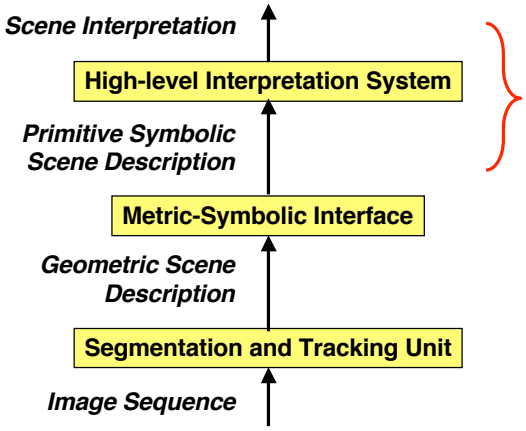
chronological backtracking

"intelligent" backtracking

backtracking with preservation of non-conflicting data

The Scene Interpretation System SCENIC

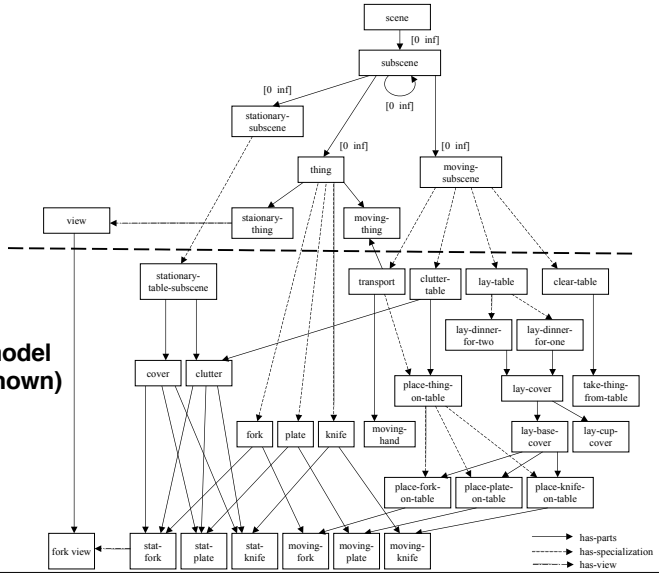
Structure of Scene-Interpretation System SCENIC



Structure of Conceptual Knowledge Base of SCENIC

upper model

domain-specific model (not all concepts shown)

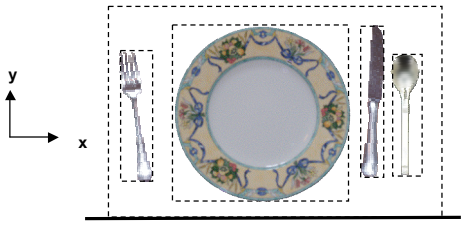


Example of Table-laying Scene

Stationary cameras observe living room scene and recognize meaningful occurrences, e.g. placing a cover onto the table.

In the following experiment: laying a table for a dinner-for-2

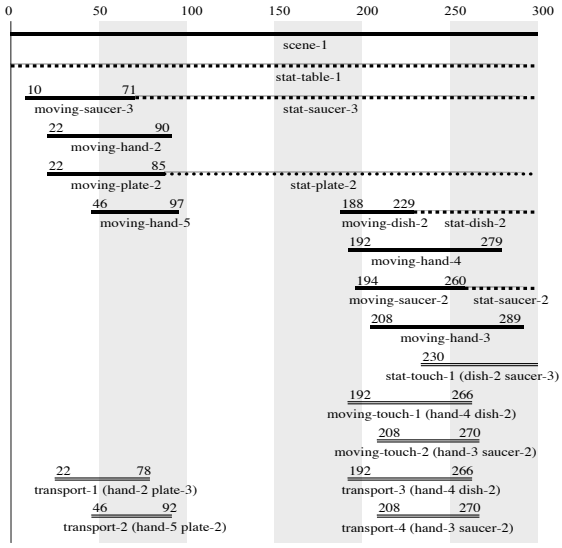
Bounding-Box Abstractions



- **object shapes are represented as 2D boxes**
- **aggregates hide internal structure**

- **box locations and distances are interval-valued**
- **value ranges and their correlations may be described by joint probability distributions**

Initial Bottom-up Instantiation of Concepts

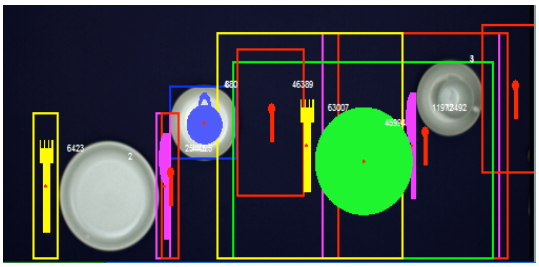


primitive stationary concepts

primitive motion concepts

aggregate concepts

Experimental Results (1)

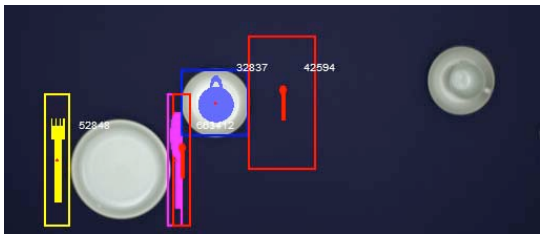


natural views = evidence
coloured shapes = hypotheses
boxes = expected locations

Intermediate state of interpretation after 51 interpretation steps:

- **"lay-dinner-for-2" hypothesis based on partial evidence**
- **predictions about future actions and locations**
- **high-level disambiguation of low-level classification**
- **influence of context**

Experimental Results (2)



- alternative interpretation in terms of top-down choices "dinner-for-one" and "cluttered-table" (after backtracking)