A COGNITIVE MODELING ASSISTANT TO OPTIMIZE COMPLEX DECISIONS

XAVIER CEUGNIET, IBM DATA AND AI
A SIMPLE SCHEDULING DEMO

AN APPROACH TO COGNITIVE MODELING

LEVERAGING YOUR OWN DOMAIN KNOWLEDGE
A SIMPLE SCHEDULING DEMO

THE COGNITIVE OPTIMIZATION FRAMEWORK

LEVERAGING YOUR OWN DOMAIN KNOWLEDGE
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AN APPROACH TO COGNITIVE MODELING

LEVERAGING YOUR OWN DOMAIN KNOWLEDGE
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LOCATED IN A MACHINE LEARNING & OPTIM. CLOUD

WATSON STUDIO

- Data Preparation
- AI Modeling
  - Machine Learning
    - SPARK-ML, SCIKIT, SPSS, AUTO AI
  - Decision Optimization
    - CPLEX, CPO, Modeling Assistant

WATSON MACHINE LEARNING

- ML Models
  - Training, Scoring
- Optim Models
  - Solving

API

USER APPLICATION

DEPLOY

INVOKER
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CAPTURING & SOLVING A DECISION MODEL

Decision Model: A set of business concepts, decision types and decision rules

- Formalizing a decision problem
- Verbalized in natural language
- Can be translated to an optimization model
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DECISION MODEL ELICITATION STEPS

- Domain Selection
- Intent Configuration
- Decision Rules Elicitation

Decision Domains:
- Scheduling
- Resource Assignment
- Selection
- Planning
...
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DECISION DOMAINS
Define a class of decision problems characterised by:

DOMAIN CONCEPTS
- Typical entities/elements entering the problem definition
  - e.g. Task, Resource, Distance matrix

INTENT TEMPLATES
- Typical problems than can be addressed
  - e.g. Schedule <tasks> and allocate <resources>

DECISIONS TYPES
- Possible decisions to be taken
  - e.g. Task start/end date, Resource-Task allocation

DECISION RULES TEMPLATES
- Pattern of business constraints, business goals, business kpis
  - e.g. Schedule must comply with <duration> of <task>
  - e.g. Maximize overall value of <assignments> w.r.t. <value table>
Decision domains are organised in an open hierarchy, where more specialised domains inherits the elements - domain concepts, decisions, intents & rules templates - defined in ancestors.
INTENT CONFIGURATION

To map the main business concepts to user data and to identify main decisions

What are the tasks and resources for scheduling?

**Definition of vocabulary**
- Activity is a Task
- Subcontractor is a Resource

**Definition of main decision types**
- Activity duration, start, end
- Subcontractor-Activity assignment
DECISION RULES ELICITATION

Elicitation relies on **Suggestions** computed by Modelling Assistant, based on:

- rule templates with verbalisation & clues
- user data, decisions,
- rules already elicited, vocabulary definitions
- optional user query, e.g:

**USER QUERY**

| activity | after | preceding | with | 2 days | delay |

**SUGGESTIONS**

- Each **Activity** starts **after** the end of **Preceding activities** with a **delay max of** 2 days
- Each **Activity** starts **after** the end of **Preceding activities** with a **delay min of** 2 days
- Each **Activity** starts **after** the end of **Preceding activities** with a **delay between** 2 days and a **maximum delay**
INFERRING VOCABULARY DEFINITION

An elicited rule may require additional vocabulary definitions on user data to be fully defined.

STEP 1: The user selects a suggested rule (an instance of a rule template)

```
DECISION RULE
Minimize overall cost of Subcontractor to Activity assignments according to Estimates
```

```
DECISION RULE TEMPLATE
Minimize overall cost of <Assignment Decisions> according to <AssignmentValue>
```

STEP 2: The Modeling Assistant deduces some definition from the rule

```
USER DATA
Estimate
```

```
DOMAIN CONCEPT
AssignmentValue
```
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DECISION RULES ELICITATION

STEP 3: The modeling assistant identifies vocabulary definitions required by the rule

- Minimize overall cost of Subcontractor to Work assignments according to Estimates
  - The resource of Estimate is defined by Subcontractor
  - The task of Estimate is defined by Work
  - The value of Estimate is must be defined

STEP 4: The definitions need to be completed before a solve can be executed

**DOMAIN CONCEPT**

AssignmentValue
- property task as Task
- property resource as UnaryResource
- property value as Numeric

**USER DATA**

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Activity</th>
<th>Subcontractor</th>
<th>K$ Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>earthwork</td>
<td>Jim</td>
<td>17</td>
</tr>
</tbody>
</table>

**REQUIRED DEFINITIONS**

- The task of Estimate is defined by Activity
- The resource of Estimate is defined by Subcontractor
- The value of Estimate is defined by K$ Estimate
When a solve is requested, the decision model is first translated to an optimization model. Rule rewriting allows to reduce complexity of the model generator associated to a domain.
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GENERATED OPTIMIZATION MODEL

- Model generated in Python, using Pandas for data & solution processing
- The model can be exported as an Notebook in Watson Studio and extended by an OR expert

```python
In [0]: from docplex.mp.utils import *
from docplex.cp.model import *
from docplex.cp.expression import _FLOATING_POINT_PRECISION
from docplex.util.environment import get_environment
import time
import operator
import pandas as pd
```

Modeling assistant can be used as a starting point for advanced optim. model
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INSIDE COGNITIVE MODELING

LEVERAGING YOUR OWN DOMAIN KNOWLEDGE

Modeling Assistant

Decide the production of Units to cover the demand on each Period

Objectives

- Minimize total costs of production of Units by Periods
- Minimize overall noxious emissions w.r.t table of Energy

Constraints

- Respect the maximum production capacity of each Unit
- The production of Units by Periods should cover forecasted demand as defined in Demand
- Global settings as first period or last period, are defined in table UC_Settings
- Respect ramp-up capacity of each Unit
- Take into account forecasted production of specific units given by table SolarEolians
LEVERAGING YOUR OWN DOMAIN KNOWLEDGE

... WITH A CUSTOM DECISION DOMAIN

- In case you are an expert of solving a type of industry-specific decision problem
- ‘Just write’ and import a custom domain in Modeling Assistant
- Allowing your decision makers or consultants with no OR skills to deliver optimization models
- E.g. Unit Commitment domain

Decide the production of Units to cover the demand on each Period

Objectives

- Minimize total costs of production of Units by Periods
- Minimize overall noxious emissions w.r.t table of Energy

Constraints

- Take into account forecasted production of specific units given by table SolarEoliens
- Respect ramp-up capacity of each Unit
LEVERAGING YOUR OWN DOMAIN KNOWLEDGE

... WITH A CUSTOM DECISION DOMAIN

- Custom domains make formulation of rules much more intuitive

THE BUSINESS CONSTRAINT

A production unit cannot be at 100% capacity at once.

Ramp-up capacity of unit should be taken into account

... WITH RESOURCE ASSIGNMENT

For each UnitPeriod, total Unit to Period allocations where allocated Unit is unit and
where allocated Period is next of period is less than or equal to
ramp_up of unit + total Unit to Period allocations where
Unit to Period allocation is joined to UnitPeriod

... WITH UNIT COMMITMENT

- Respect ramp-up capacity of each Unit
  The nextPeriod of Period is defined by next
  The firstPeriod of UC_Settings is defined by firstPeriod
  The lastPeriod of UC_Settings is defined by lastPeriod
  The initialProd of Unit is defined by initial_prod
  The rampUp of Unit is defined by ramp_up

+ similar one for first period...
By inheriting elements from an internal domain, a custom domain writer can focus on adding domain specific business concepts, decision types, rule templates (intents, goals, constraints, kpis).

Writing optimization generation code is only required for rules that cannot be rewritten as rules of parent domain.
FUTURE WORK

Improve suggestions

by better NL query processing

by learning about solutions

Improve smart visualisation

Visualisation is key for business experts to evaluate quality of a model

Improve industry covering

Build a community of decision domain contributors
THANKS!

Q&A

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