LOGIC PROGRAMMING IN A CONSTRUCTION PLANNING WORKBENCH

Generation of a draft construction schedule from an IFC model

(3D to 4D CAD)

A CRC-CI Research Project

- **Research Project –**
- **CRC-CI 2002-056-C: Contract Planning Workbench**
- **It investigates the feasibility of generating a draft construction schedule from an IFC repository, that is an automatic 3D to 4D CAD process**

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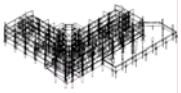
3D to 4D Transformation

Building Information Model

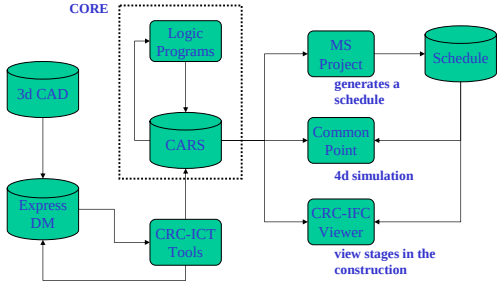


C – Identify building components
A – Associate construction activities
R – Estimate required resources
S – Define sequence of activities

CPW

Draft Construction Schedule

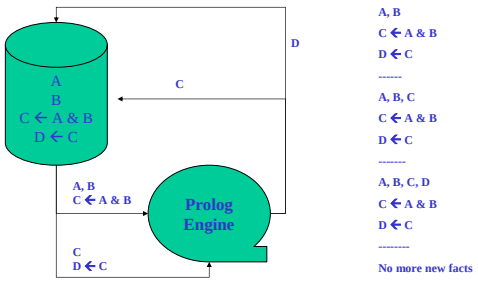
System Architecture



Logic Programming

- **A declarative and relational style of programming based on first-order logic**
- **PROLOG - original logic programming based on Horn clauses**
- **A programmer writes a "database" of "facts", e.g. human("Gerry") and "rules", e.g. mortal(X) :- human(X).**

Simple Prolog Example



Logic Programming in CPW

A is a reinforced concrete beam
B is a reinforced concrete slab
A is connected to B

A and B are constructed together

IF (X is a reinforced concrete beam) AND
(Y is a reinforced concrete slab) AND
(X is connected to Y)
THEN (X and Y are constructed together)

Relationships Between Elements

- **Connected: Column (C) is connected to beam (B)**
- **Supports: Footing (F) supports column (C)**
- **Constructed before: Footing (F) constructed before column (C)**
- **Constructed together: Slab (S) and beam (B) are constructed together**
- **Connected but not supported: Ground slab (G) is connected to, but not supported by column (C)**

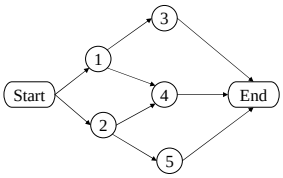
Output of CPW

- List of building elements or components (C)
- List of construction activities associated with the building components (A)
- List of required resources (R)
- Sequence logic between activities (S)

ID	Name	Duration	Predecessors
1	place reinforcement of columns	3.5 hrs	10
2	place formwork of columns	19.3 hrs	1
3	pour concrete of columns	2.5 hrs	2
4	wait for concrete of columns to cure	40 hrs	3
5	strip formwork of columns	9.5 hrs	4
	.....		
11	wait for concrete of footings to cure	40 hrs	10

Table fragment listing construction activities and their precedence relations

Precedence Constraints



Duration:
Task 1: 5 days
Task 2: 6 days
Task 3: 9 days
Task 4: 4 days
Task 5: 5 days

IF $i \in$ Predecessors(j) THEN
Start(i) + Duration(i) ≤ Start(j)

Start(1) ≥ 0
Start(2) ≥ 0
Start(3) ≥ Start(1) + 5
Start(4) ≥ Start(1) + 5
Start(4) ≥ Start(2) + 6
Start(5) ≥ Start(2) + 6

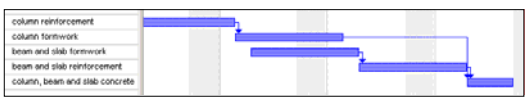
Predecessors(i) = {j | (j,i) ∈ Edges}
Predecessors(4) = {1, 2}

Successor(i) = {j | (i,j) ∈ Edges}
Successor(1) = {3, 4}

Tasks + Precedence = Schedule

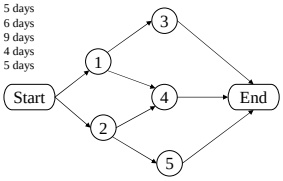
Construction sequence when reinforced concrete columns, beams and slabs are erected monolithically:

- column reinforcement
- column formwork
- scaffolding and formwork for beams and slabs
- beam and slab reinforcement
- column, beam and slab concrete



Resource Constraints

Duration:
Task 1: 5 days
Task 2: 6 days
Task 3: 9 days
Task 4: 4 days
Task 5: 5 days



Resources Required:
Task 1: 1 unit R1 + 5 units R2
Task 2: 2 units R1 + 2 units R2
Task 3: 2 units R1 + 4 units R2
Task 4: 2 units R1 + 3 units R2
Task 5: 3 units R1 + 2 units R2

Resources Available:
5 units of R1
7 units of R2

At any given time, the amount of resources in used is less than or equal to the amount of resources available.

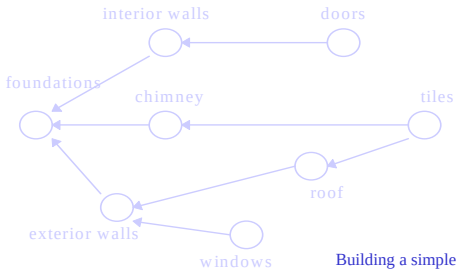
Task 1 and Task 2 can proceed concurrently, but Task 3, Task 4 and Task 5 can not proceed concurrently as required resources will exceed available resources

Another Output of CPW

ID	Name	Duration	Predecessors	Resources
21	place formwork	3.9 hrs	5,14	carpenter[400%],labourer[400%]
22	place reinforcement	0.7 hrs	16,21	steel tradesman[400%]
23	pour concrete	0.9 hrs	17,22	concrete mixer,concrete tradesman[400%],labourer[400%],trowelling machine
24	cure conrete	40 hrs	18,23	
25	strip formwork	1.8 hrs	19,24	labourer[400%]

Prepared as an ODBC data source for MS Project (version 2003)

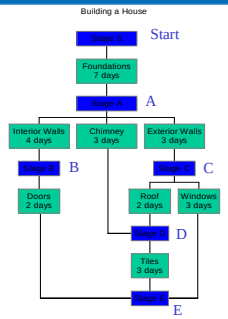
Simply a Graph



Building a simple house

Using Constraint Programming

start	$T_S \geq 0$
foundations	$T_A \geq T_S + 7$
interior walls	$T_B \geq T_A + 4$
exterior walls	$T_C \geq T_A + 3$
chimney	$T_D \geq T_A + 3$
roof	$T_D \geq T_C + 2$
doors	$T_E \geq T_B + 2$
tiles	$T_E \geq T_D + 3$
windows	$T_E \geq T_C + 3$



Constraint Logic Programming

- **A programming framework based (like Prolog) on first-order logic with a constraint solver added**
- **CLP = LP + Constraint Solver**
- **Can be more efficient in certain problems such as scheduling, planning and resource allocation**

Thank You ☺