University timetabling By using Constraint Satisfication Problem

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Motivation

Using CONSTRAINT SATISIFICATION PROBLEM SOLVER to automatically create a time table and solve constraints among below resources:

$$Time, Lectures, Teachers, Rooms$$

Goals:

1. Assign $Lecture$ to $Time$
2. Assign $Lecture$ to $Room$

Introduction to CSP

Constraint satisfaction problem (CSP) deals with assignment of values from its domains to each variable such that no constraint is violated. CSP has three components:

$$variables, domains, constraints$$

CSP consists of(Dechter, R., 2003):
A finite set of variable $X = \{X_0, X_1, \ldots, X_n\}$ with respective domains $D = \{D_0, D_1, \ldots, D_n\}$ which list the possible values for each variable $D_i = \{v_i, \ldots, v_k\}$ and a set of constraints $C = \{C_0, C_1, \ldots, C_t\}$

CSP model of Variables and Domains

Let:

- $CS = \{CS_0, CS_1, \ldots, CS_n\}$ is a set of **courses**
- $L = \{L_0, L_1, \ldots, L_k\}$ is a set of **lectures**
- $T = \{T_0, T_1, \ldots, T_j\}$ is a set of available teaching **timeslots**
- $R = \{R_0, R_1, \ldots, R_g\}$ is a set of available teaching **Rooms**
- $P = \{P_0, P_1, \ldots, P_m\}$ is a set of **teachers**
- $L_i(student)$ is the number of students who enrolled lecture where $L_i \in L, 0 < i < k$
- $L_i(major)$ is the major of lecture where $L_i \in L, 0 < i < k$
- $L_i(teacher)$ is the teacher of lecture where $L_i \in L, 0 < i < k$, $P_s \in P, 0 < s < j$
- $T_i(weekday)$ is the weekday of time slot where $T_i \in T, 0 < i < j$
- $CS_i \in CS$ is course may contains a set of lectures,eg. $CS_i = \{L_a, L_b, L_c\}$ where $0 < a/b/c < k$
- $R_i(limit)$ is the limit number of students of the room where $R_i \in R, 0 < i < g$
- $P_i(time)$ is the set of timeslots that the teacher P_i is available where $P_i \in P, 0 < i < m$

Goals are to assign $lectures$ to $timeslots$ and $room$ with satisfying a lot of constrains. So we could determine **Variables** here.
We have two set of **Variables**:

1. RL_i represents the class **room** of lecture L_i where $L_i \in L$, i from 0 to k with **domain** R
2. TL_i represents the **timeslot** of lecture L_i where $L_i \in L$, i from 0 to k with **domain** T

After determining variables and domains, the next step is to determine constrains and encode it.

CSP model of Complusory Constraints

$Complusory\ constraints$:

1. Lectures in the same major should be assigned in different time slot.
   $TL_i \neq TL_j$ if $L_i(major) = L_j(major)$ where $L_i, L_j \in L$
2. Teacher can only teache one lecture in a time slot.
   $TL_i \neq TL_j$ if $L_i(teacher) = L_j(teacher)$ where $L_i, L_j \in L$
3. Lecture can only be assigned to room if the students number is less than the room's limit.
   $RL_i \neq R_j$ if $L_i(student) \geq R_j(limit)$ where $L_i \in L, R_j \in R$
4. Room can only be assigned to one lecture at the same time
   $RL_i \neq RL_j$ if $TL_i = TL_j$ where $i \neq j$

CSP model of Soft Constraints

$Soft\ constraints$:

1. Lecture should be assigned in teacher's available time slots.
   $TL_i \in P_j(time)$ where $P_j \in P$
2. The same course's lectures should not be in the same day
   $TL_i(weekday) \neq TL_j(weekday)$ if $CS_i = CS_j$

Encoding constraints

$Complusory\ constraints$:

1. To Divide lectures by majors $ML_i \subset L$, and then put each set into AlldifferentConstraint
2. According to constraint one, only different majors' lectures may conflict.So it should only be concerned is that different majors' lectures. To make pairs of lectures with different majors but the same teacher, and then put them into InEqualConstraint.
3. To calculate each lecture's available rooms $ARL_i \subset R$, and then use InSetConstraint to narrow the domain of each $RL_i \in RL$
4. This constraint just influences lectures of different majors.So we make pairs of different majors' lecture and use FunctionalConstraint to compare TL_i, RL_i, TL_j, RL_j

$Soft\ constraints$:

1. To narrow the domain of each lectures' available time slot by calculating the teacher's available time slot. We use InSetConstraint to deal with it.
2. To use FounctionConstraint to assign different weekdays of time slot to lectures

Experimental Evaluation

Approach tested over one non–trivial dataset. This dataset is generated randomly according to the model and it has solutions.

Name	$lecture$	$room$	$teacher$	$timeSlot$	$major$
NUMBER	15	8	3	40	3

Because timetabling is a NP problem, in experiment, i just get one correct solution for different solvers and compare their time:

Solver	$encodingTime$	$solutionTime$
BACKTRACKINGSOLVER	0.003s	0.096s
RECURSIVEBACKTRACKINGSOLVER	0.00075s	0.075s
MINCONFLICTSSOLVER	0.0003s	0.300s

From the table, MinConflictsSolver is much lower than the other solvers,i guess the reason is that at the initial state, we did not assign any value to variable. Here is one result of timetabling:

```
begin to get solution:
busi1233s2 at R1 time is T18 Wed 9:00-10:00 teacher is weinan zhang
engn1200s2 at R1 time is T20 Wed 11:00-12:00 teacher is yinbo yang
busi1000s1 at R1 time is T6 Mon 13:00-14:00 teacher is weinan zhang
busi1000s2 at R1 time is T17 Wed 8:00-9:00 teacher is weinan zhang
busi1233s1 at R1 time is T7 Mon 15:00-16:00 teacher is weinan zhang
engn2333s2 at R2 time is T10 Tue 9:00-10:00 teacher is yinbo yang
engn6666s1 at R1 time is T12 Tue 11:00-12:00 teacher is yinbo yang
engn6666s2 at R1 time is T19 Wed 10:00-11:00 teacher is yinbo yang
engn1200s1 at R1 time is T13 Tue 12:00-13:00 teacher is yinbo yang
comp6320s2 at R1 time is T25 Thur 8:00-9:00 teacher is yuanxin wei
engn8400s1 at R2 time is T9 Tue 8:00-9:00 teacher is yuanxin wei
comp2222s2 at R2 time is T17 Wed 8:00-9:00 teacher is yinbo yang
comp6320s1 at R1 time is T10 Tue 9:00-10:00 teacher is yuanxin wei
comp6442s3 at R1 time is T8 Mon 17:00-18:00 teacher is yinbo yang
comp2222s1 at R1 time is T11 Tue 10:00-11:00 teacher is yinbo yang
comp6442s1 at R1 time is T5 Mon 12:00-13:00 teacher is yinbo yang
comp6442s2 at R1 time is T9 Tue 8:00-9:00 teacher is yinbo yang
engn8400s2 at R1 time is T26 Thur 9:00-10:00 teacher is yuanxin wei
engn2333s1 at R2 time is T18 Wed 9:00-10:00 teacher is yinbo yang
getting solutions phase costs 0.074490070343 seconds
```

From the result, we can see lectures are planned into different weekdays. This is because of soft constraint two. If not, the result will be assgined mostly in one or two days one by one.

Conclusions & Future Work

- CSP solvers can be used to get solution of timetabling but the performance is related to constraints.
- **Constraint**: In this problem, time slot is not flexible. If a lecture is two hours long, it can not solve based on above constraints. *must–see* actions.
- **FutherWork**: Using AC-3 to narrow domains and Considering the situation if time over timeslot.