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Logic Formulation and Evaluation of Academic Constraints

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Abstract

University curriculum scheduling is a prominent research issue of resources optimization. The problem consists of constraints, composite event variables and their placement domains. This research work introduces a novel set of evaluation heuristics those sharply scan out the dataset with respect to hard or soft constraints and consequently assign penalties to conflicting events. The research approach is examined over a number of diverse benchmark dataset where complexity increases with subject to their number of events, constraints and curriculums. Furthermore, each dataset is classified over six complexity scales where each scale is differentiated set of constraints. The prime advantages are revealed from the research work to acquire accurate status of constraints violations with respect to various datasets and complexity scales which leads to obtain optimal solution in short span of time and using less computational resources.

Keywords: *Evaluation Function, Hard Constraints, Benchmark datasets, Penalty function*

1 Introduction

Academic Scheduling is an important combinatorial optimization problem. The problem can be defined by assignment of instructors, courses and room under various types of constraints. The key objective is to minimize number of conflicts and maximize resources utilization. The problem is widely considered as challenging resources assignment job since interdependent constraints take into account. The classic scheduling problem precisely illustrated by constraints, composite variables (events), finite domain of values and violation penalty costs.

The typical solution consists to assign the suitable site (venue or room), personnel resource (teacher) on defined time length (working day and timeslot) for the enrolled group of students (Curricula). The framework schema is separated under two types, the hard and the soft constraints. In practice, the hard constraints are mandatorily required to be satisfied under all circumstances. In fact, a solution qualifies essential feasible state if only, all the hard constraints conflicts get resolved. Nearly all the hard constraints are commonly adapted and exercised in academic institutes; nevertheless several types of soft constraints can be at variance from each other with subject to their own educational priorities. The research work presented in this article causes the successful outcome of relevant work (Aftab Ahmed *et al.*, 2011a)

- Time Elements (Days, Periods and timeslots): A five to six number of teaching/working days are usually exercised. Each day is divided into predetermined duration of various sessions in some cases in range of three to six. A timeslot is single entry of lecture event. A period contains a stack of timeslots, maximum number of rooms can provide larger stack of timeslots.
- Courses and curriculum: A course is offered to group of students which may be separated in multiple sessions throughout the week. On the other hand a curriculum is correlated set of courses which usually comprises over rudiments (prerequisite), optional (elective) and mandatory (core) courses. Student(s) can get enrollment in a range of courses to be bound with curricula.
- Physical resources (Class Room, Lab and Multimedia Projector etc.): the necessity of technical equipment like projector, smart board etc or required venue like auditorium or seminar hall etc which is highly desirable to particular event.

Next section takes a look on state-of-the-art development in the field of scheduling. In section Three, typical curriculum problem has been illustrated categorically. At the first, timetabling terminology is described. The most important components of timetabling, the hard and soft constraints are sorted out which are handled globally in most of the problem instances. Afterward, benchmark instances are described with distinguished classifications which contain five conventional and one additional complexity scale. Constraints are exemplified through figures and mathematical equations.

2 Related Work

The classic university scheduling is described as (M.W. Carter and Laporte, 1998): *“a multi-dimensional assignment problem in which students, teachers (or faculty members) are assigned to courses, course sections or classes; events (individual meetings between students and teachers) are assigned to classrooms and times”* In combinatorial optimization problem such as curriculum scheduling, a fitness or heuristic function keeps immense importance in general. An evaluation function (M. Adriaen *et al.*, 2003) is scale of constraints violations and their relevant cost parameters. Ghaemi (Ghaemi *et al.*, 2007) draw an evaluation function that examine an array of constraints subject to constant plenty. Nevertheless, sometimes evaluation function is supposed to produce bit more quality performance when it is used to exploit the resources usage. In addition, ideally an evaluation function is designed purposely to acquire non violated outcome, which is someway not likely in huge and complex real world or benchmarks datasets and eventually it has to compromise over small number of unsolved soft violations.

Every scheduling issue can be recognized by Constraint Satisfaction Problem (CSP) that comprises over three key elements finite set of variables, their domains and hard &soft constraints (V, D, and C). The merits (W. Legierski, 2002) of CLP is stated *"a straightforward statement of the constraints serves as part of the program. This makes the program easy to modify, which is crucial in real-world problems"* in addition, (G. M. White and J. Zhang, 1998) *"when problems are formulated as constraint logic problems they become known as Constraint Satisfaction Problems, (CSP)".*

Aftab and Li (Aftab Ahmed and Li, 2010) successfully solved a read world case study using Constraint Satisfaction Problem in two separate phases where first one completely sweep out hard constraints and later the second phase deliberately deals only with the soft constraints. Their extended work in (Aftab Ahmed *et al.*, 2011b) appended another phase to acquire very optimal outcome by implementation of Genetic Algorithm over partial solution.

3 Problem Explanation

The combinatorial problem consists of numerous variables and constraints including Teacher, class rooms, courses, time-slots and group of student. Precisely Scheduling Problem = [I, T, C, S, G]. Curriculum schema is categorized under two major types, hard and soft constraints. The set of hard constraints (HC) is decisively required not to be satisfied. In contrary, all the soft constraints cannot be removed from the benchmark as well as real world dataset so highest degree of soft satisfaction places the solution on higher order of quality scale.

3.1 Constraints and Dynamic Penalty Scale

As it is discussed, Hard Constraints should be resolved under all circumstances. Generally, an inclusive set of constraints is immersed in most of the academic institutes; though a certain number of adapted constraints are also fabricated. The possibility of violation likely rises while two or more events need a shared resource at the same time.

Penalty formulation comprises over several algorithms, each algorithm scan out the dataset for particular constraint and if conflict finds then stamp that event penalty cost. The cost mounts with affiliated conflict with that event. The penalty schema is precisely illustrated in 3.2.2 Classroom Conflicts (HC2): No more than one lecture evens should be given to a teacher, a hard violation is counted in such case. Conflicted pair of events is assigned by equal penalty but every time penalty multiplies with repeated occurrence of the violation. E.g. Layout.Slot = HC. Penalty × $\sum_{k=1}^{n} \boldsymbol{E\,vt}$

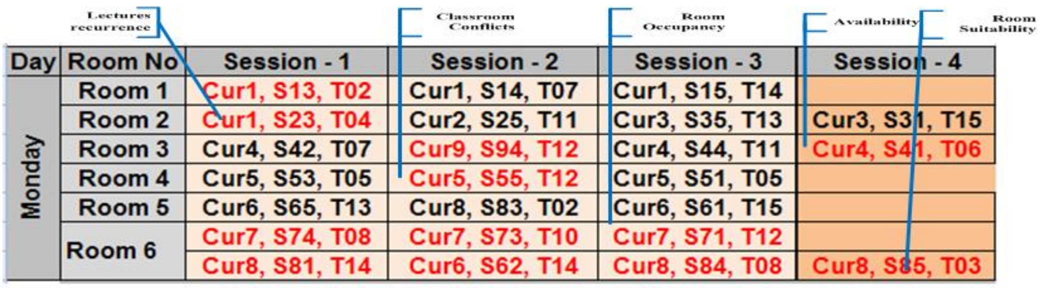
$$\sum_{\mathrm{i=1}}^{\mathrm{Peroid}} \sum_{\mathrm{j=1}}^{\mathrm{Faculty}} \mathrm{f_j \,.\, c_i} \leq 1 \tag{3.2}$$

Table **1** that dynamically grow complex on the basis of each scale. This penalty schema (conflicting cost of hard and soft constraints violations) is advised by Bonutti (Alex Bonutti *et al.*, 2010) however in this research paper, one advanced complexity scale is appended for all benchmark datasets to examine solving capability of research approach. Each complexity scale brings up the diverse penalty weights and intensity in for identical constraints. Moreover, number of constraints and lecture events increases in with respect to available resources. These discrepancies stand each dataset different from other so consequently it requires generic as well as robust evaluation and solving approaches. The constraints which are recognized by variables HC (Hard Constraint) in 3.2.2 Classroom Conflicts (HC2): No more than one lecture evens should be given to a teacher, a hard violation is counted in such case. Conflicted pair of events is assigned by equal penalty but every time penalty multiplies with repeated occurrence of the violation. E.g. Layout.Slot = HC. Penalty × $\sum_{k=1}^{n} \boldsymbol{E\,vt}$

$$\sum_{\mathrm{i=1}}^{\mathrm{Peroid}} \sum_{\mathrm{j=1}}^{\mathrm{Faculty}} \mathrm{f_j \,.\, c_i} \leq 1 \tag{3.2}$$

Table **1** are mandatory for the state of feasible solution whereas rests of the group is known as soft constraints.

3.2 Hard Constraints Description



Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Monday	Room 1	Cur1, S13, T02	Cur1, S14, T07	Cur1, S15, T14	
	Room 2	Cur1, S23, T04	Cur2, S25, T11	Cur3, S35, T13	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T12	Cur4, S44, T11	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
		Cur8, S81, T14	Cur6, S62, T14	Cur8, S84, T08	Cur8, S85, T03

Fig: exclusively depicts the different types of hard constraints, multiple assignments of curriculum (Cur1 under HC_1 tag) at the same time and session causes violation.

Similarly replication of resource person highlighted with tag HC_3 in room 3 and 4 respectively. The violation HC_3 is taken place due to not inadequate seating availability in room number 6; on the other hand HC_4 is happened because of prior notified unavailability of teacher T06. HC_5 is special type of hard or soft constraint depends on the complexity scale and institutional need. As it is observed in session four, manifold events are assigned in the same venue and time cause HC_5 to take place.

3.2.1 Lectures recurrence (HC_1): Multiple events should not be assigned to a group of students concurrently.

$$\sum_{i=1}^{Peroid} \sum_{j=1}^{Courses} g_i c_j \leq 1 \quad (3.1)$$

3.2.2 Classroom Conflicts (HC2): No more than one lecture evens should be given to a teacher, a hard violation is counted in such case. Conflicted pair of events is assigned by equal penalty but every time penalty multiplies with repeated occurrence of the violation. E.g. Layout.Slot = HC. Penalty × $\sum_{k=1}^{n} \boldsymbol{E\ vt}$

$$\sum_{i=1}^{Peroid} \sum_{j=1}^{Faculty} f_j \,.\, c_i \leq 1 \quad (3.2)$$

Table 1 Problem classification description

Var.	Type	Constraint Title	$Scale_1$	$Scale_2$	$Scale_3$	$Scale_4$	$Scale_5$	$Scale_6$
HC_1	Hard Constraints	Lectures recurrence	∞	∞	∞	∞	∞	∞
HC_2		Room Conflicts	∞	∞	∞	∞	∞	∞
HC_3		Room Occupancy	∞	∞	∞	∞	∞	∞
HC_4		Availability	∞	∞	∞	∞	∞	∞
HC_5		Room Suitability	-	-	3	∞	-	-
SC_1	Soft Constraints	Room Capacity	1	1	1	1	1	-
SC_2		Min Working Days	5	5	-	1	5	5
SC_3		Isolated Lectures	1	2	-	-	1	2
SC_4		Windows	-	-	4	1	2	1
SC_5		Room Stability	-	1	-	-	-	2
SC_6		Student Min Max Load	-	-	2	1	2	1
SC_7		Travel Distance	-	-	-	-	2	-
SC_8		Double Lectures	-	-	-	1	-	-
SC_9		Teaching Max Load	-	-	-	-	-	5

3.2.3 Room Occupancy (HC3): Two concurrent lecture events cannot be assigned in a single venue; each such conflict multiplies the penalty cost.

$$\sum_{i=1}^{rooms} \sum_{j=1}^{Evnts} r_i \,.\, e_j \leq 1 \quad (3.3)$$

3.3.3 Room Suitability (HC4): The Class room must sufficiently be equipped with necessary hardware for example multimedia projector, white/black board etc.

$$\sum_{i=1}^{rooms} \sum_{j=1}^{goups} r_{ik} \,.\, g_j \leq 1 \text{where } \forall k \in \{1 \cdots \text{Room. Equipments}\} \quad (3.4)$$

3.3.4 Availabilty (HC5): Event should not be assigned if instructor has declared unavailability on a certain specific time because of any valid reason.

$$\sum_{i=1}^{\text{Faculty}} \sum_{j=1}^{\text{Events}} f_i \,.\, e_j <> True \qquad (3.5)$$

3.3 Soft Constraints Description

In most of the cases almost all the hard constraints are widely available in universities however the quality scale largely depends upon the violation presence of soft constraints.

3.4 Complexity Scale 1

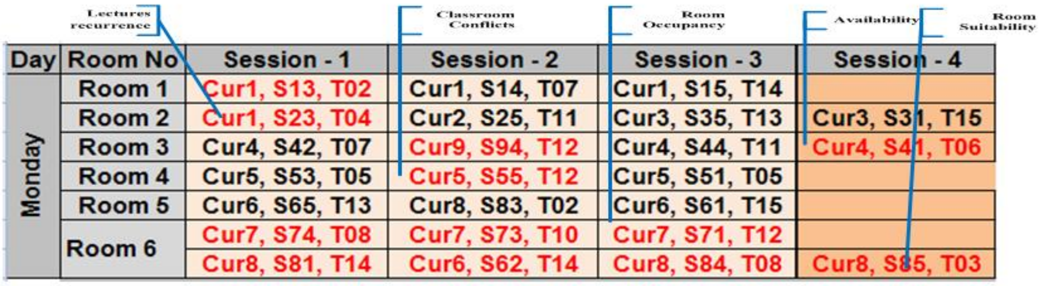
This scale comprises over four hard and three soft constraints; penalty cost Algorithm/criterion is defined bellow.

3.4.1 SC_1 (Room Capacity): Number of students exceeding the class-room seating capacity would be counted a violation.

$$\sum_{i=1}^{\text{rooms}} \sum_{j=1}^{\text{goups}} r_{ik} \,.\, g_j \le 1 \text{where } \forall k \in \{1 \cdots \text{Room. Capacity}\} \qquad (3.6)$$

3.4.2 SC_2 (Min Working Days): Courses should be ordered and separated with predetermined number of sessions over working days.

$$\sum_{i=1}^{\text{Days}} \sum_{j=1}^{\text{Cours}} d_i c_j \ge s_i \; where \; \forall k \in \{1 \cdots \text{Course. Sessions}\} \qquad (3.7)$$



Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Monday	Room 1	Cur1, S13, T02	Cur1, S14, T07	Cur1, S15, T14	
	Room 2	Cur1, S23, T04	Cur2, S25, T11	Cur3, S35, T13	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T12	Cur4, S44, T11	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
		Cur8, S81, T14	Cur6, S62, T14	Cur8, S84, T08	Cur8, S85, T03

Fig. 2: Hard Constraints Demonstration

Procedure: Room Capacity

Def Min_Working_Days:

1. **IF** Event.Students < Room.Capacity:
2. Layout[Penalty_Slot] =(Room.Capacity - Event.Students) × Scale.Penalty
3. **EndIf**

Procedure: Min Working Days

Def Min_Working_Days:
1. Fixtures = Call Events_Counter():
2. **IF** Fixtures < Min_Working_Days:
3. Layout [Penalty_Slot] = (Min_Working_Days - Fixtures) × Scale.Penalty
4. **EndIf**

Procedure: Isolated Lectures

1. **Def** Isolated_Events:
2. **For** All Day Events:
3. **IF** CountDay (Event)== 1:
4. Layout[Penalty_Slot] = Scale.Penalty
5. **EndIf**
6. **End While**

3.4.3 SC$_3$ (Isolated Lectures): Generally contiguous lecture events are appreciated by student, the window between events causes a soft violation and penalty adds up with each identical occurrence.

$$\sum_{i=1}^{Days} \sum_{j=1}^{Cours} d_i c_j \leq 1 \text{ where } \forall k \in \{1 \cdots \text{Course. Sessions}\} \tag{3.8}$$

3.5 Complexity Scale 2

This level is extended with one new constraint.

3.5.1 SC$_5$ (Room Stability): Succeeding event(s) of each student group should be placed on the same room/venue. Number of different rooms in sequence events multiply penalty. e.g.

$$\sum_{i=1}^{groups} \sum_{j=1}^{events} \beta_{ik} = \text{Room} \tag{3.9}$$

Procedure: Room Stability

1. **Def** Room_Stability:
2. **For** All Day Events:
3. **IF** Sequence_Placments(Event)== NOT Stable:
4. Layout[Penalty_Slot] = $\sum_1^n$ Room. Violations × Scale.Penalty
5. **EndIf**
6. **End_LOOP**

3.6 Complexity Scale 3

The scale is extended by three new soft constraints defined as bellow.

3.6.1 SC$_4$ (Windows): The empty bubbles (sessions) between two relevant events of one group are considered as soft violations.

$$\sum_{i=1}^{Events} |e_i - e_{i+1}| = 1 \tag{3.10}$$

Procedure: Windows between Events

1. **Def** Windws_Peroids:
2. **For** All Day Events in Day:
3. PenaltyCounter = $Event_i$ - $Event_J$
4. **IF** PenaltyCounter:
5. Layout[Penalty_Slot] = PenaltyCounter × Scale.Penalty
6. **EndIf**
7. **End_LOOP**

Isolated Lectures | Room Capacity

Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Room 1	Cur1, S13, T02	Cur1, S14, T07	Cur1, S15, T14	
	Room 2	Cur9, S23, T04	Cur2, S25, T11	Cur3, S35, T13	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T19	Cur4, S44, T11	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
	Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	Cur8, S85, T03

Fig 3: Soft Constraints from Scale 1

Isolated Lectures | Room Capacity

Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Room 1	Cur1, S13, T02	Cur1, S14, T07	Cur1, S15, T14	
	Room 2	Cur9, S23, T04	Cur2, S25, T11	Cur3, S35, T13	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T19	Cur4, S44, T11	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
	Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	Cur8, S85, T03

Fig 3: represents the two soft violations from complexity scale 1.
Lecture event in Room 7 of session 3 is only single assignment of that curriculum.

Room Stability

Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Room 1	Cur10, S13, T02	Cur1, S14, T07	Cur11, S17, T19	
	Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur3, S35, T13	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T19	Cur1, S15, T14	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
	Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	Cur8, S85, T03

Fig 4 Distinct Soft Constraint of Scale 2

Room Stability

Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Room 1	Cur10, S13, T02	Cur1, S14, T07	Cur11, S17, T19	
	Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur3, S35, T13	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T19	Cur1, S15, T14	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
	Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	Cur8, S85, T03

Fig. 4: portrays the exclusive properties of complexity scale 2, while the rest of constraints are derived from previous scale.

3.6.2 SC$_6$ (Student MinMax Courses Load): Lecture events must be confined with the limit of (lower and upper bond) sessions assigned to any group of students.

$$\sum_{i=1}^{\text{Groups}} \sum_{j=1}^{\text{Events}} \beta_{ik} \geq \text{LB} \;\&\; \leq \text{UB} \tag{3.11}$$

Windows

Student MinLoad

Student Max Load

Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Room 1	Cur10, S13, T02	Cur1, S14, T07	Cur10, S13, T02	Cur1, S10, T02
	Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur3, S35, T13	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T19	Cur1, S15, T14	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
	Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	Cur8, S85, T03

Fig 5: Distinct Soft Constraints from Scale 3

Windows

Student MinLoad

Student Max Load

Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Room 1	Cur10, S13, T02	Cur1, S14, T07	Cur10, S13, T02	Cur1, S10, T02
	Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur3, S35, T13	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T19	Cur1, S15, T14	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
	Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	Cur8, S85, T03

Fig 5: reveals the bespoke constraints of complexity scale 3, other constraints of this scale are shared with previous scales.

Timeslot at location (Room-1, Session-1 and Session-2) clearly exhibits two events of same group in nonconsecutive session; such gap is actually undesirable and counts as soft violation. The cell point (Room-2, Session-2) stands for the isolated lecture event. Conversely the lecture events in (Room-2,1,3,1 and Sessions-1,2,3,4 respectively) view the additional number of events assigned in single day for particular curricula which causes the soft violation.

3.7 Complexity Scale 4

This scale inherits previous constraints including new one called Double Lecture constraint.

3.7.1 SC_8 (Double Lecture): Sometimes a long sessions or accumulated session is required especially in executive/evening programs or on teacher demand.

$$\sum_{i=1}^{Events} \sum_{j=1}^{Sessions} |t_i - t_{i+1}| = 1 \qquad (3.12)$$

Procedure: Double Lecture

1. **Def** Windws_Peroids:
2. **For** All Day Events in Week:
3. SessionGape$_i$ = Cur$_i$.Event$_i$ - Cur$_j$.Event$_j$
4. **IF** Not Any $\sum_1^n$ SessionGape$_i$ = 0
5. Layout[Penalty_Slot] = Scale.Penalty.Double
6. **EndIf**
7. **End_LOOP**

Double Lecture

Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Room 1	Cur10, S13, T02	Cur2, S14, T07	Cur10, S13, T02	
	Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur1, S14, T07	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T19	Cur1, S14, T07	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
	Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	Cur8, S81, T14

Fig 6: Distinct Sot Scale from Scale 4

Double Lecture

Day	Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Room 1	Cur10, S13, T02	Cur2, S14, T07	Cur10, S13, T02	
	Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur1, S14, T07	Cur3, S31, T15
	Room 3	Cur4, S42, T07	Cur9, S94, T19	Cur1, S14, T07	Cur4, S41, T06
	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
	Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
	Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
	Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	Cur8, S81, T14

Fig 6: shows the Doubled Lecture constraint violated at (Room-1and 2, Sessions-3).

3.8 Complexity Scale 5

The scale addresses the travelling between venue/buildings.

3.8.1. Travel Distance: Conflict violation recorded if events of same group are assigned in different buildings on same day.

$$\sum_{i=1}^{\mathrm{Events}} S_i . b_j \; = 1 \text{ where } \forall j \; \in \{1 \cdots \mathrm{Vanue}\} \tag{3.13}$$

Procedure: Venue

Def Venue_Stability:
For All Day Events:
IF Sequence_Placments(Event$_i$)== NOT Same Venue:
Layout[Penalty_Slot] = $\sum_1^n \mathrm{Venue.Violations} \times$ Scale.Penalty
EndIf
End_LOOP
End_LOOP

Travel Distance

Day		Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Building 1	Room 1	Cur10, S13, T02	Cur2, S14, T07	Cur10, S13, T02	
		Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur1, S14, T07	Cur3, S31, T15
		Room 3	Cur4, S42, T07	Cur8, S81, T14	Cur1, S14, T07	Cur4, S41, T06
	Building 2	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	
		Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
		Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
		Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur10, S84, T20	

Fig 7 Soft Constraint from Scale 6

Fig 7 portrays the timetabling divided into two building so consequently on some it causes the violations.

3.9 Complexity Scale 6

The scale originates a new constraint Teaching Work Load along with rest of others.

3.9.1 Teaching Work Load: If teaching work assignments go beyond the upper bond it may be raised with identical number of violations.

$$\sum_{i=1}^{\mathrm{Faculty}} S_i . b_j \; \leq \mathrm{LB} \;\; where \; \forall j \; \in \{1 \cdots \mathrm{TeachingLoad}\} \tag{3.14}$$

Procedure: Teacher Max Load

Def TeacherMaxLoad:
For Scan DayEvents:
Range = Counts ($\sum_{1}^{n}$ Teacher. Events)
IF Range > TeacherLoad.UB:
Layout[Penalty_Slot] = Scale.Penalty × Range - TeacherLoad.UB
EndIf
End_LOOP

Teaching Load

Day		Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Building 1	Room 1	Cur10, S13, T02	Cur2, S14, T07	Cur10, S13, T02	
		Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur1, S14, T07	Cur3, S31, T15
		Room 3	Cur4, S42, T07	Cur8, S81, T14	Cur1, S14, T07	Cur4, S41, T06
	Building 2	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	Cur5, S51, T05
		Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
		Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
		Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur6, S60, T14	

Fig 1 Distinguished Soft Constraints

Teaching Load

Day		Room No	Session - 1	Session - 2	Session - 3	Session - 4
Day 1	Building 1	Room 1	Cur10, S13, T02	Cur2, S14, T07	Cur10, S13, T02	
		Room 2	Cur1, S13, T02	Cur2, S25, T11	Cur1, S14, T07	Cur3, S31, T15
		Room 3	Cur4, S42, T07	Cur8, S81, T14	Cur1, S14, T07	Cur4, S41, T06
	Building 2	Room 4	Cur5, S53, T05	Cur5, S55, T12	Cur5, S51, T05	Cur5, S51, T05
		Room 5	Cur6, S65, T13	Cur8, S83, T02	Cur6, S61, T15	
		Room 6	Cur7, S74, T08	Cur7, S73, T10	Cur7, S71, T12	
		Room 7	Cur8, S81, T14	Cur6, S62, T14	Cur6, S60, T14	

Fig 1 demonstrates the three consecutive teaching events in such a case where upper limit is declared as two lectures per day.

4 Results

The experiential outcome of evaluation logic/function validates the accuracy and efficiency. The computational approach is investigated over a wide range of benchmark datasets. Table 2 portrays the results of the ten benchmark instances (classified over six separate complexity scales). All the problem instances differ from each other on the basis of various parameters counting problem depth, venue saturation and resource limitations etc.
Complexity Scale -1 encloses four permanent hard constraints (HC_1, HC_2, HC_3 and HC_4) and also three soft constraints (SC_1, SC_2 and SC_3). The evaluation

function (coded in python language) extract out the violations against all types of constraints. In particular, the constraint HC_4 is removed due to scheduling layout design and placement of events.

The HC_2 has comparatively bigger chance of occurrence replications as enormous numbers of courses are shared by various curriculums simultaneously. Usually, the HC_5 violation happened when shared or visiting faculty is involved. It is mandatory in all the scales to eliminate hard constraints first. A single hard constraint violation even stands solution misfit/unfeasible. In complexity scale-1 the soft constrain (SC_1) identifies the Room Capacity. It was elaborated that each added student more than the available seats in class room increases violation counter. SC_2 and SC_3 are also showing their presence in the datasets. Total penalty costs of each complexity scale mounts with respect to dataset, due to increasing number of events, saturation and escalating complexity.

Scale-4 in Table 2 demonstrates the Double Lectures (SC_8) constraints; the provision sometimes is required by visiting faculty. Travel distance (SC_7) is another important constraint which is shown in higher level of Scale number 5. Scale-6 is representing work load constraint named Teaching Load (SC_9). The removal of constraint violation provides comfort to teachers to produce quality work.

5 Conclusions

The Research work has addressed important issues including the evaluation function and penalty schema. The vast manmade of relevant field and computational experience is incorporated for designing the evaluation function (set of heuristics). Promising outcome is acquired by implementation on the various benchmark datasets which evidently endorse the accuracy in research direction.

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Table 2 Results of Evaluating Constraints of 10 datasets

	Complexity Scales	Lectures	Conflicts	Room Occupancy	Availability	R Suitability	R Capacity	MW Days	Isolated	Windows	R Stability	St Min Max Load	Travel Distance	Double Lectures	Teaching Max Load	
Comp01	Sacle1	16	60	0	11		46	30	9							172
	Sacle2	16	60	0	11		46	30	9		115					287
	Sacle3	16	60	0	11	26	46			16		32				207
	Sacle4	16	60	0	11	26	46	30		16		32		3		240
	Sacle5	16	60	0	11		46	30	9	16		32	11			231
	Sacle6	16	60	0	11			30	9	16	115	32			6	295
Comp02	Sacle1	23	134	0	74		79	46	70							426
	Sacle2	23	134	0	74		79	46	70		513					939
	Sacle3	23	134	0	74	42	79			28		57				437
	Sacle4	23	134	0	74	42	79	46		28		57		6		489
	Sacle5	23	134	0	74		79	46	70	28		57	19			530
	Sacle6	23	134	0	74			46	70	28	513	57			11	956
Comp03	Sacle1	26	101	0	56		513	42	76							814
	Sacle2	26	101	0	56		513	42	76		423					1237
	Sacle3	26	101	0	56	34	513			25		50				805
	Sacle4	26	101	0	56	34	513	42		25		50		5		852
	Sacle5	26	101	0	56		513	42	76	25		50	47			936
	Sacle6	26	101	0	56			42	76	25	423	50			10	809
Comp04	Sacle1	20	103	0	51		84	37	78							373
	Sacle2	20	103	0	51		84	37	78		313					686
	Sacle3	20	103	0	51	34	84			29		57				378
	Sacle4	20	103	0	51	34	84	37		29		57		6		421
	Sacle5	20	103	0	51	34	84	121	78	29		57	19			596
	Sacle6	20	103	0	51			121	78	29	313	57			11	783
Comp05	Sacle1	7	52	0	61		60	405	243							828
	Sacle2	7	52	0	61		60	405	243		264					1092
	Sacle3	7	52	0	61	19	260			250		330				979
	Sacle4	7	52	0	61	19	260	405		250		330		156		1540
	Sacle5	7	52	0	61		260	405	243	250		330	150			1758
	Sacle6	7	52	0	61			405	243	250	264	330			6	1618
Comp06	Sacle1	32	118	0	101		95	62	82							490
	Sacle2	32	118	0	101		95	62	82		474					964
	Sacle3	32	118	0	101	38	95			36		72				492
	Sacle4	32	118	0	101	38	95	62		36		72		7		561
	Sacle5	32	118	0	101		95	62	82	36		72	56			654
	Sacle6	32	118	0	101			62	82	36	474	72			14	991
Comp07	Sacle1	52	156	0	138		121	87	145							699
	Sacle2	52	156	0	138		121	87	145		501					1200
	Sacle3	52	156	0	138	48	121			43		87				645
	Sacle4	52	156	0	138	48	121	87		43		87		9		741
	Sacle5	52	156	0	138		121	87	145	43		87	29			858
	Sacle6	52	156	0	138			87	145	43	501	87			17	1226
Comp08	Sacle1	67	134	0	182		93	65	120							661
	Sacle2	67	134	0	182		93	65	120		432					1093
	Sacle3	67	134	0	182	40	93			32		65				613
	Sacle4	67	134	0	182	40	93	65		32		65		6		684
	Sacle5	67	134	0	182		93	65	120	32		65	22			780
	Sacle6	67	134	0	182			65	120	32	432	65			13	1110
Comp09	Sacle1	22	104	0	49		75	88	93							431
	Sacle2	22	104	0	49		75	88	93		388					819
	Sacle3	22	104	0	49	41	75			28		56				375
	Sacle4	22	104	0	49	41	75	88		28		56		6		469
	Sacle5	22	104	0	49		75	88	93	28		56	19			534
	Sacle6	22	104	0	49			88	93	28	388	56			11	839
Comp10	Sacle1	21	129	0	91		95	42	59							437
	Sacle2	21	129	0	91		95	42	59		552					989
	Sacle3	21	129	0	91	47	95			37		74				494
	Sacle4	21	129	0	91	47	95	42		37		74		7		543
	Sacle5	21	129	0	91		95	42	59	37		74	25			573
	Sacle6	21	129	0	91			42	59	37	552	74			15	1020