CHAPTER 6

PLANNING AND SCHEDULING CONSTRAINTS

6.1 INTRODUCTION

AI Planning and Scheduling (P&S) has become a successful and widely used technique. It allows us to generate a sequence of activities that achieves, a set of goals, having in mind the time and resources available, as presented by Allen (1991) who generated a plan (sequence or parallelization of activities) such that it achieves a set of goals, given an initial state and satisfying a set of domain constraints represented in operators’ schemas.

A planning is the task of learning, formulating the sequence of actions needed to achieve certain goals. Hence a solution to planning problem when carried out will ensure achieving the desired goals of e-learner. In scheduling systems, activities are organized along the time line considering the resources available. Scheduling has to face the problem of organizing tasks in time. The problem is to locate a set of tasks in time; each task requires one or several resources for its execution.

Constraint solving deals with finding solutions to CSPs. It refers to the techniques that enable constraint programming, a branch of declarative programming, where instead of implementing an algorithms; the programmer models the problem as a CSP, and uses a constraint solver to construct a solution.
6.2 PLANNING FOR SPORTS ACTIVITY

With respect to the Sports domain training activity, planning is involved in sequence of sports e-learners’ actions; for example, in an athletic event 100mts the sequence of actions involves position (move), selection of parameters (take), running activity (in case of some deviations, the selection of alternative actions (load)) and reaching the running end point. In the e-learner, the plans before the training activities are represented in Table 6.1. An e-learner in sports domain can handle the physical activity based on the values of the physiological variables. Based on the physical activity undergoing the e-learner is named as sprinter, runner or player etc.

Table 6.1 Describes the various positions of the e-learner

<table>
<thead>
<tr>
<th>Position</th>
<th>Learner/ e-learner Action</th>
<th>Activity(Pre-condition)</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting position</td>
<td>Move (e-learner, onyourmark, set. go Reach point)</td>
<td>At(e-learner), position(from on your mark), clear(track), clear(e-learner)</td>
<td>Ready point (e-learner)</td>
</tr>
<tr>
<td>Middle position</td>
<td>Move (e-learner track, Reach point)</td>
<td>At(e-learner,track), clear (track), clear (e-learner)</td>
<td>Run(e-learner)</td>
</tr>
<tr>
<td>End position</td>
<td>Move (e-learner, track, reach position)</td>
<td>At(e-learner, track), clear(track), clear (e-learner), position (to reach point)</td>
<td>Achieve task (reach position)</td>
</tr>
</tbody>
</table>

The starting point describes the starting position of the e-learner. The e-learner will get ready at the marked position of the track. When the umpire gives the instruction “on your mark”, “set”, “go” the e-learner will
start running along the track. In the middle of the track the verifiers will check
the running track of the e-learner, and at the end the e-learner will achieve the
goal by reaching the target point. With initial position appropriate e-learner
action and preconditions (constraints), goal to be achieved is decided upon.

6.3 SCHEDULING FOR SPORTS ACTIVITY

The CSP has been applied to different scheduling Problems with
very good results. A CSP problem has inputs like the domain values as the set
of variables and the constraints for the variables. The output of the scheduling
systems is the value that fulfills all the constraints of the variables.

A sports training activity of scheduling problems can be
represented as a constraint-satisfaction problem, by representing the attributes
of tasks and resources as variables. A schedule is represented as an
assignment of values to the variables. Task attributes include the scheduled
start and end time, and a resource assignment. The variables Sbegin and Egoal
are used to represent the beginning and the end of the task. The primary
attribute of resources is the availability (i.e., down-time and work schedules).
A schedule is constructed by assigning times and resources to tasks, while
obeying the constraints of the problem.

Each machine can only process one job at a time. Each job can only
be processed by one machine at any time. Once a machine has started
processing a job, it will continue running on that job until the job is finished.

6.3.1 Athletic E-learner Physiological Variables

The Athletic event e-learner physiological variable is modeled as a
CSP, where a finite set of variables, a function which maps every variable to a
finite domain, and a finite set of constraints restricting the values that the
variables can simultaneously take, are declared as follows.

However, the variables are only properly declared when learners
are assigned to a matchup (meeting between two teams). The CSP then
consists of a Constraint Network (CN): (L, D, C) where,

A set of e-learners,  \( EL = \{e_{l1}, e_{l2}, \ldots, e_{ln}\} \) is the set of variables.

A set of domains,  \( D = \{D(e_{l1}), D(e_{l2}), D(e_{l3}), \ldots, D(e_{ln})\} \) where \( D(e_{li}) \) a
finite set of Possible values for e-learners \( li \), where \( li \) refers to the e-learners
\( i = \{1, 2, \ldots, 8\} \).

In this problem, domains are the service order (time slots).

- A set of constraints related to e-learners, \( C = \{c_1, c_2, \ldots, c_k\} \).

- Objective: To declare a winner among the elements satisfying
  the constraints given below for a physical running activity.

**Constraint 1:** Every e-learner should run in the track along with
other e-learner in a scheduled time.

**Constraint 2:** The time slot varies based on the running time of
the e-learner, related to the length of the e-learner’s run.

**Constraint 3:** The timeslot varies from 1 sec to 13sec (men
e-learner) and 1 sec to 15sec (women e-learner) seconds.

**Constraint 4:** The e-learner should run in own track. Other
tracks should be avoided.
**Constraint 5:** The e-learner is eligible even when the e-learner falls during the run.

**Constraint 6:** The e-learner should reach the end point before 13 to 15 seconds.

**Constraint 7:** The e-learner can be declared a winner when e-learner takes the least time to reach the point.

**Constraint 8:** The e-learner can touch the end point even with e-learner hand.

### 6.3.1.1 Activity time assignment

- Processing Activity (PA) is an entity occupying some space (resources) and time

- Variables and their domains for each activity for time assignment
  
  \[\text{start}(PA) = \{\text{est}(PA), \ldots, \text{lct}(PA) - p(A1\ldots A8)\}\}

  \[\text{end}(PA) = \{(\text{est}(PA) + p(A1\ldots A8)), \ldots, \text{lct}(PA)\}\}

  Activity must finish before the deadline
  
  \[\text{lct}(PA) = \max(\text{end}(A)), \text{latest completion time}\]
Table 6.2  Time scheduling for Men and Women e-learners running activity (100mts)

<table>
<thead>
<tr>
<th>E-learners</th>
<th>Earliest Physiological Variable (Before start)</th>
<th>Earliest Start Time (micro Sec)</th>
<th>Latest Completion Time (sec)(task)</th>
<th>Latest Physiological Variable (after completion)</th>
<th>Processing Activity (PA) Time (sec)</th>
<th>Service Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>e1(Men)</td>
<td>HRhigh (range 70)</td>
<td>0.02</td>
<td>12.3</td>
<td>Normal</td>
<td>12.28</td>
<td>3(Men)</td>
</tr>
<tr>
<td>e2(Women)</td>
<td>Normal</td>
<td>0.01</td>
<td>13.0</td>
<td>Normal</td>
<td>12.99</td>
<td>2(Women)</td>
</tr>
<tr>
<td>e3(Women)</td>
<td>BP(D)high (range 132)</td>
<td>0.02</td>
<td>12.1</td>
<td>Normal</td>
<td>12.08</td>
<td>1(Women)</td>
</tr>
<tr>
<td>e4(Men)</td>
<td>HRhigh (range 72)</td>
<td>0.03</td>
<td>10.3</td>
<td>Normal</td>
<td>10.27</td>
<td>2(Men)</td>
</tr>
<tr>
<td>e5(Men)</td>
<td>BP(D)high (range 135)</td>
<td>0.02</td>
<td>9.8</td>
<td>Normal</td>
<td>9.78</td>
<td>1(Men)</td>
</tr>
<tr>
<td>e6(Women)</td>
<td>HRhigh (range 74)</td>
<td>0.02</td>
<td>15.0</td>
<td>Normal</td>
<td>14.98</td>
<td>4(Women)</td>
</tr>
<tr>
<td>e7(Women)</td>
<td>Normal</td>
<td>0.01</td>
<td>14.5</td>
<td>Normal</td>
<td>14.4</td>
<td>3(Women)</td>
</tr>
<tr>
<td>e8(Women)</td>
<td>BP(D)high (range 140)</td>
<td>0.04</td>
<td>13.2</td>
<td>Normal</td>
<td>13.16</td>
<td>4(Women)</td>
</tr>
</tbody>
</table>

Table 6.2 gives the details of eight e-learners running in the 100mts event. The time assignment is derived based on the physiological parameters (Heart rate and Blood Pressure). Earliest stage physiological parameters indicates the ability of the sports e-learners to complete the task. When all the earliest physiological parameter are supporting the e-learner to undertake the event (activity), implies that the e-learner has sufficient resources to accomplish the task. The Earliest physiological parameters help identifying the parameter which is not in range. Administering the suitable supplements to bring the physiological variables in to the limit, this enables the e-learner to undertake activity or achieve the goal.
6.3.2 Resource Scheduling

Resource scheduling can be classified as preemptive scheduling and non preemptive scheduling. Preemptive scheduling is prioritized. The highest priority process should always be the currently utilized process.

6.3.2.1 Non preemptive activity

In Non Preemptive activity scheduling, when the process enters the running state, the state of the process is not deleted from the scheduler until it completes the service time. Refer Figure 6.1: Non preemptive activity scheduling.

From the **beginning to the end no interruption** occurs during the training activity. Runners concentrate on how to follow the starting point position, the track instruction, and reach the goal. Participants think before the activity that no interruption occurs during the activity.

Start (PA) + p (A1…A8) = end (PA)

![Figure 6.1 (Continued)](image-url)
Figure 6.1 No interruption occurs during the training activity

Table 6.3 Performance analysis of non preemptive activity scheduling

<table>
<thead>
<tr>
<th>e-learners</th>
<th>Earliest Physiological variable(Before start)</th>
<th>Earliest start time(micro Sec)</th>
<th>Latest completion Time(sec)(task)</th>
<th>Latest Physiological variable(after completion)</th>
<th>Processing activity(PA) time(sec)</th>
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<tr>
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<td>e2(Women)</td>
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</tr>
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<td>e8(Women)</td>
<td>BP(D)high (range 140)</td>
<td>0.04</td>
<td>13.2</td>
<td>Normal</td>
<td>13.16</td>
</tr>
</tbody>
</table>
6.3.2.2 Preemptive activity

The preemptive activity scheduling feature allows a high-priority task to preempt a running activity of lower priority. The lower-priority task is suspended and is resumed as soon as possible. Use preemptive scheduling, if it is running activity; the low-priority task has to wait an unacceptably long time. Refer Figure 6.2: Interruption occurs during the training activity.

![Figure 6.2 Interruption occurs during the training activity](image-url)
Table 6.4 Performance analysis of preemptive activity scheduling

<table>
<thead>
<tr>
<th>E-learners</th>
<th>Earliest Physiological Variable (Before start)</th>
<th>Earliest Start Time (micro Seconds)</th>
<th>Interruption During Running activity (Sec)</th>
<th>Latest Completion Time (sec)</th>
<th>Latest Physiological Variable (after completion)</th>
<th>Processing Activity (PA) Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>el1(Men)</td>
<td>HR high (range 70)</td>
<td>0.02</td>
<td>1.2sec (8.5sec)</td>
<td>12.3</td>
<td>Normal</td>
<td>10.28</td>
</tr>
<tr>
<td>el2(Women)</td>
<td>Normal</td>
<td>0.01</td>
<td>1sec (10.2sec)</td>
<td>15.0</td>
<td>Normal</td>
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<td>0.02</td>
<td>1sec (9.8sec)</td>
<td>12.1</td>
<td>Normal</td>
<td>11.07</td>
</tr>
<tr>
<td>el4(Men)</td>
<td>HR high (range 72)</td>
<td>0.03</td>
<td>2sec (5.6sec)</td>
<td>10.3</td>
<td>Normal</td>
<td>8.27</td>
</tr>
<tr>
<td>el5(Men)</td>
<td>BP(D) high (range 135)</td>
<td>0.02</td>
<td>2sec (5.2sec)</td>
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<td>1sec (10.2 sec)</td>
<td>13.2</td>
<td>Normal</td>
<td>12.16</td>
</tr>
</tbody>
</table>

In Table 6.4, the e-learner gets interrupted at the start position of activity or while running. When eight sports e-learners are involved in the training activity, the starting position is normal. When an interruption occurs in this activity, failure condition occurs. But in the middle some e-learners’ fall down or misplace the track. Later the participants corrects the position and begins to run (Backtrack problem) during the training activity. So the completion time/end point is minimum for this kind of e-learner. Some e-learners do not continue the running activity and may go out of the track. This type of condition is termed as failure condition.

The CSP solver is an important concept in the constraint satisfaction Problem. It is a template of all the physiological variables stored.
The CSP solver enables the e-learner to query the sports related activity and get the desired result through the web. Also the physiological variables that satisfy the sufficient condition are made available by the CSP solver. The functionality of the CSP solver is described fellow.

6.4 CSP SOLVER

In general CSP solvers may be efficient search solvers or stochastic search solvers. A CSP solver accepts a CSP as input and returns a solution to the system, if there is no such solution or break. The CSP solver gets the rule from the CSP and is in e-learner understandable form. The respective for constraints satisfied in this rules are depicted in the solver. The rules are very useful in the training activity for the sports person. If the document is huge, the e-learner (user) finds it difficult to understand the concept during the activity. However if the e-learner uses a step by step process the rule can be understood in a very efficient and effective manner. If the e-learner understands the rule, the training activity period for changing the physiological variable depends on climate condition such as hot and cool climate. Yet another condition is how to change the physiological variables for the body condition (tension, stress). Even if the physiological changes occur before the start of the training the CSP solver can handle conditions of the physiological variable and provide solution for recovery during the training activity.

The CSP solver component implemented accepts CSP as input in the form of simple rules; for example 1.

If SPEED is LOW
then BP is NORMAL
else if RR is HIGH
then SD is MEDIUM
In first example the constraints are not equal in the training activity. If the speed is low the BP is normal. So the e-learner’s running is normal in the training activity. If the speed of the e-learners is high then BP is low; in this case it will be a backtrack problem.

If during the training activity, the RR is high, the stamina is medium. The e-learner before starting (planning) the training activity or competition time has to analyze how much distance (scheduling); body condition is suitable for this game, what should be taken in the middle of running activity.

Sometimes if the e-learner or runner may fall down in the middle of the ground; and the BP is high then HR is also high. Sometimes the e-learner goes into a critical condition. So the training activity the e-learner should maintained for all the factors such as health, food, field of work etc.

The complete information of the sports domain is stored in the template. On satisfying the CSP, the CSP solver component provides the user with the optimal solution by using the rule developed by the system, for users to gain knowledge of the training activity.

Example 2 illustrates e-learner Blood Pressure (BP), E-learner Heart Rate (HR), E-learner Respiratory Rate (RR) as given below.

I. **E-learner BP**

#1

All People have Normal BP or High BP or Low BP.

E-learner is a person.

E-learner Learns training activity.
Training activity shows BP is high, BP is low.

E-learner does training activity.

∀ P(x)  =>  (Normal BP(x) v High BP(x) v Low BP(x))

L(X)  =>  person(x)

TA(x)  =>  (High BP(x) v Low BP(x)) ^ (High BP(x) ^ Low BP(x))

L(X)  =>  TA(X)

**Proof**

∀ X P(x) => [Normal BP(x) v High BP(x) v Low BP(x)]  Premises

L(x) ^ Person(x)  Premises

Learns (training activity, E-learner(x))  Premises

∀ X training activity(x) => [(high BP(x) v low BP(x))^high BP(x) ^ low BP(x))]  

**Universal specification**

∀ Does(x, training activity) => [(high BP (x) v low BP (x)) ^ (high BP (x) ^ low BP(x))]  

**Universal specification**

∀ Does (e-learner(x), training activity) =>[(high BP(x)vlowBP(x))^high BP(x) ^ low BP(x))]  

**Rule of attachments**

Hence it is proved that training activity is influenced by Normal, High and Low BP.

**#2**

Some people have a normal BP.

E-learner is a people.
All E-learners have a training activity.

Training activity shows High BP or Low BP

**Proof**

\[ \exists \quad P(x) \implies \text{Normal BP}(x) \quad \text{Premises} \]

\[ L(x) \implies P(x) \quad \text{Premises} \]

\[ \forall \quad L(X) \implies TA(x) \quad \text{Premises} \]

\[ TA(x) \implies (\text{High BP}(x) \lor \text{Low BP}(x)) \land (\text{High BP}(x) \land \text{Low BP}(x)) \quad \text{Universal specification} \]

\[ L(X) \implies (\text{High BP}(x) \lor \text{Low BP}(x)) \quad \text{Rule of attachments} \]

Therefore e-learner may possess high or Low BP

\[ L(X) \implies \neg \text{Normal BP}(x) – \text{True} \]

\[ L(X) \implies \text{Normal BP}(x) – \text{False} \]

Hence, it is proved that the training activity is influenced by High or Low BP.

**II. E-learner Heart Rate**

#1

All People have Normal HR or High HR or Low HR.

E-learner is a person.

E-learner Learns training activity.
Training activity shows HR is high, HR is low.

E-learner does training activity.

\[ \forall \ P(x) \implies (\text{Normal HR}(x) \lor \text{High HR}(x) \lor \text{Low HR}(x)) \]

\[ \text{L}(X) \implies \text{person}(x) \]

\[ \text{TA}(x) \implies (\text{High HR}(x) \lor \text{Low HR}(x)) \land (\text{High HR}(x) \land \text{Low HR}(x)) \]

\[ \text{L}(X) \implies \text{TA}(X) \]

**Proof**

\[ \forall \ X \ P(x) \implies [\text{Normal HR}(x) \lor \text{High HR}(x) \lor \text{Low HR}(x)] \quad \text{Premises} \]

\[ \text{L}(x) \land \text{Person}(x) \quad \text{Premises} \]

Learns (training activity, E-learner(x)) \quad \text{Premises}

\[ \forall \ X \ \text{training activity}(x) \implies [(\text{high HR}(x) \lor \text{low HR}(x)) \land (\text{high HR}(x) \land \text{low HR}(x))] \]

**Universal specification**

\[ \forall \ \text{Does (x, training activity)} \implies [(\text{high HR}(x) \lor \text{low HR}(x)) \land (\text{high HR}(x) \land \text{low HR}(x))] \]

**Universal specification**

\[ \forall \ \text{Does (e-learner(x), training activity)} \implies [(\text{high HR}(x) \lor \text{low HR}(x)) \land (\text{high HR}(x) \land \text{low HR}(x))] \]

**Rule of attachments**

Hence it is proved that training activity is influenced by Normal, High and Low HR.

#2

Some people have a normal HR.

E-learner is a people.
All E-learners have a training activity.

Training activity shows High HR or Low HR

**Proof**

\[ \exists x \ P(x) \Rightarrow \text{Normal HR}(x) \]  \hspace{1cm} \text{Premises}

\[ L(x) \Rightarrow \ P(x) \]  \hspace{1cm} \text{Premises}

\[ \forall x \ L(x) \Rightarrow \text{TA}(x) \]  \hspace{1cm} \text{Premises}

\[ \text{TA}(x) \Rightarrow (\text{High HR}(x) \lor \text{Low HR}(x)) \land (\text{High HR}(x) \land \text{Low HR}(x)) \]  \hspace{1cm} \text{Universal specification}

\[ L(x) \Rightarrow (\text{High HR}(x) \lor \text{Low HR}(x)) \]  \hspace{1cm} \text{Rule of attachments}

Therefore e-learner may possess high or Low HR

\[ L(x) \Rightarrow \neg \text{Normal HR}(x) \Rightarrow \text{True} \]

\[ L(x) \Rightarrow \text{Normal HR}(x) \Rightarrow \text{False} \]

Hence, it is proved that the training activity is influenced by High or Low HR. During the training activity the e-learner learns which type of physiological variable is suitable for e-learner health condition, that is, Medium, Normal, High, or Low, which is obtained by the reasoning done by the system

So two types of rules are used for the sports training activity e-learner. It is not document based content.
6.5 SUMMARY

The various constraints for the e-learner have been set forth in the above with all the various possibilities, and the time slots are properly mentioned. An elaborate presentation has been done on Non preemptive and preemptive scheduling. The various data of planning and scheduling, explained in detail in this chapter are stored in the CSP solver, and the information is used by the e-learner through the e-learning System.