**Velammal College of Engineering and Technology, Madurai**

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**UNIT IV**

**PLANNING AND MACHINE LEARNING**

Basic plan generation systems - Strips -Advanced plan generation systems – K strips -Strategic explanations -Why, Why not and how explanations. Learning- Machine learning, adaptive Learning.

**Basic plan generation systems & STRIPS**

* Components of a Planning System
* Example: Block World Problem
* STRIPS Mechanism
* Simple planning using a Goal Stack
* Sussman anomaly problem

**Planning**

* Planning refers to the process of computing several steps of a problem solving before executing any of them.
* Planning is useful as a problem solving technique for non decomposable problem.

**Components of a Planning System**

* + Choose the best rule (based on heuristics) to be applied
  + Apply the chosen rule to get new problem state
  + Detect when a solution has been found
  + Detect dead ends so that new directions are explored.
* **Choose Rules to apply**

Most widely used technique for selecting appropriate rules is to

* + First isolate a set of differences between the desired goal state and current state,
  + Identify those rules that are relevant to reducing these difference,
  + If more rules are found then apply heuristic information to choose out of them.
* **Apply Rules**

In simple problem solving system,

* + Applying rules was easy as each rule specifies the problem state that would result from its application.
  + In complex problem we deal with rules that specify only a small part of the complete problem state.

**Example:Block World Problem**

* Block world problemassumptions
  + Square blocks of same size
  + Blocks can be stacked one upon another.
  + Flat surface (table) on which blocks can be placed.
  + Robot arm that can manipulate the blocks. It can hold only one block at a time.
* In block world problem, the state is described by a set of predicates representing the facts that were true in that state.
* One must describe for every action, each of the changes it makes to the state description.
* In addition, some statements that everything else remains unchanged is also necessary.

**Actions (Operations) done by Robot**

* UNSTACK (X, Y) : **[US (X, Y)]**
  + Pick up X from its current position on block Y. The arm must be empty and X has no block on top of it.
* STACK (X, Y): **[S (X, Y)]**
  + Place block X on block Y. Arm must holding X and the top of Y is clear.
* PICKUP (X): **[PU (X) ]**
  + Pick up X from the table and hold it. Initially the arm must be empty and top of X is clear.
* PUTDOWN (X): **[PD (X)]**
  + Put block X down on the table. The arm must have been holding block X.

**Predicates used to describe the state**

* + ON(X, Y) - Block X on block Y.
  + ONT(X) - Block X on the table.
  + CL(X) - Top of X clear.
  + HOLD(X) - Robot-Arm holding X.
  + AE - Robot-arm empty.

**Logical statements true in this block world**

* + Holding X means, arm is not empty

(∃ X) HOLD (X) → ~ AE

* + X is on a table means that X is not on the top of any block

(∀ X) ONT (X) → ~ (∃ Y) ON (X, Y)

* + Any block with no block on has clear top

(∀ X) (~ (∃ Y) ON (Y,X)) → CL (X)

**Effect of Unstack operation**

* The effect of US(X, Y) is described by the following axiom

[CL(X, State) Λ ON(X, Y, State)] →

[HOLD(X, DO(US (X, Y), State)) Λ CL(Y,DO(US(X, Y), State)) ]

* + DO is a function that generates a new state as a result of given action and a state.
* For each operator, set of rules (called frame axioms) are defined where the components of the state are
  + affected by an operator
    - If US(A, B) is executed in state S0, then we can infer that HOLD (A, S1) Λ CLEAR (B, S1) holds true, where S1 is new state after Unstack operation is executed.
  + not affected by an operator
    - If US(A, B) is executed in state S0, B in S1 is still on the table but we can’t derive it. So frame rule stating this fact is defined as ONT(Z, S) → ONT(Z, DO(US (A, B), S))
* Advantage of this approach is that
  + Simple mechanism of resolution can perform all the operations that are required on the state descriptions.
* Disadvantage is that
  + Number of axioms becomes very large for complex problem such as COLOR of block also does not change.
  + So we have to specify rule for each attribute.

COLOR(X, red, S) →

COLOR(X, red, DO(US(Y, Z), s))

* To handle complex problem domain, there is a need of mechanism that does not require large number of explicit frame axioms.

**STRIPS MECHANISM**

* One such mechanism was used in early robot problem solving system named STRIPS
* In this approach, each operation is described by three lists.
  + Pre\_Cond list contains predicates which have to be true before operation.
  + ADD list contains those predicates which will be true after operation
  + DELETE list contain those predicates which are no longer true after operation
* Predicates not included on either of these lists are assumed to be unaffected by the operation.
* Frame axioms are specified implicitly in STRIPS which greatly reduces amount of information stored.

**STRIPS – Style Operators**

* S (X, Y)
  + Pre: CL (Y) Λ HOLD (X)
  + Del: CL (Y) Λ HOLD (X)
  + Add: AE Λ ON (X, Y)
* US (X, Y)
  + Pre: ON (X, Y) Λ CL (X) Λ AE
  + Del: ON (X, Y) Λ AE
  + Add: HOLD (X) Λ CL (Y)
* PU (X)
  + Pre: ONT (X) Λ CL (X) Λ AE
  + Del: ONT (X) Λ AE
  + Add: HOLD (X)
* PD (X)
  + Pre: HOLD (X)
  + Del: HOLD (X)

Add: ONT (X) Λ AE

**Simple Planning using a Goal Stack**

* One of the earliest techniques is planning using goal stack.
* Problem solver uses single stack that contains
  + sub goals and operators both
  + sub goals are solved linearly and then finally the conjoined sub goal is solved.
* Plans generated by this method will contain
  + complete sequence of operations for solving one goal followed by complete sequence of operations for the next etc.
* Problem solver also relies on
  + A database that describes the current situation.
  + Set of operators with precondition, add and delete lists.

**Algorithm**

* Let us assume that the goal to be satisfied is:

GOAL = G1 Λ G2 Λ … ΛGn

* Sub-goals G1, G2, … Gn are stacked with compound goal G1 Λ G2 Λ …Λ Gn at the bottom.

Top G1

G2

:

Gn

Bottom G1 Λ G2 Λ … Λ G4

* At each step of problem solving process, the top goal on the stack is pursued.
* Find an operator that satisfies sub goal G1 (makes it true) and replace G1 by the operator.
  + If more than one operator satisfies the sub goal then apply some heuristic to choose one.
* In order to execute the top most operation, its preconditions are added onto the stack.
  + Once preconditions of an operator are satisfied, then we are guaranteed that operator can be applied to produce a new state.
  + New state is obtained by using ADD and DELETE lists of an operator to the existing database.
* Problem solver keeps track of operators applied.
  + This process is continued till the goal stack is empty and problem solver returns the plan of the problem.

**Goal stack method – Example**

* Logical representation of Initial and Goal states:
  + Initial State: ON(B, A) Λ ONT(C) Λ ONT(A) Λ ONT(D) Λ CL(B) ΛCL(C) Λ CL(D) Λ AE
  + Goal State: ON(C, A) Λ ON(B, D) Λ ONT(A) Λ ONT(D) Λ CL(C) Λ CL(B) Λ AE



* We notice that following sub-goals in goal state are also true in initial state.

ONT(A) Λ ONT(D) Λ CL(C) Λ CL(B) Λ AE

* Represent for the sake of simplicity - **TSUBG**.
* Only sub-goals ON(C, A) & ON(B, D) are to be satisfied and finally make sure that TSUBG remains true.
* Either start solving first ON(C, A) or ON(B, D). Let us solve first ON(C, A).

**Goal Stack:**

ON(C, A)

ON(B, D)

ON(C, A) Λ ON(B, D) Λ TSUBG

* To solve ON(C, A), operation S(C, A) could only be applied.
* So replace ON(C, A) with S(C, A) in goal stack.

**Goal Stack:**

S (C, A)

ON(B, D)

ON(C, A) Λ ON(B, D) Λ TSUBG

* S(C, A) can be applied if its preconditions are true. So add its preconditions on the stack.

**Goal Stack:**

CL(A)

HOLD(C) Preconditions of STACK

CL(A) Λ HOLD(C)

**S (C, A)** Operator

ON(B, D)

ON(C, A) Λ ON(B, D) Λ TSUBG

* To satisfy the goal HOLD(C), two operators can be used e.g., PU(C ) or US(C, X), where X could be any block. Let us choose PU(C ) and proceed further.
* Repeat the process. Change in states is shown below.

**State\_1:**

ONT(A) ΛONT(C) Λ ONT(D) Λ HOLD(B) ΛCL(A) Λ CL(C) ΛCL(D)

**SQUEUE = US (B, A)**

* Next operator to be popped of is S(B, D). So

**State\_2:**

ONT(A) ΛONT(C) Λ ONT(D) Λ ON(B, D) ΛCL(A) Λ CL(C) ΛCL(B)ΛAE

**SQUEUE = US (B, A), S(B, D)**

**State\_3:**

ONT(A) ΛHOLD(C) Λ ONT(D) Λ ON(B, D) ΛCL(A) ΛCL(B)

**SQUEUE = US (B, A), S(B, D), PU(C )**

**State\_4:**

ONT(A) ΛON(C, A) Λ ONT(D) Λ ON(B, D) ΛCL(C) ΛCL(B) ΛAE

**SQUEUE = US (B, A), S(B, D), PU(C ), S(C, A)**

**Difficult Problem:**

* The Goal stack method is not efficient for difficult problems such as Sussman anomaly problem.
* It fails to find good solution.
* Let us consider the Sussman anomaly problem



***Initial State:***ON(C, A) Λ ONT(A) Λ ONT(B)

***Goal State:*** ON(A, B) Λ ON(B, C)

* Remove CL and AE predicates for the sake of simplicity.
* To satisfy ON(A, B), following operators are applied

***US(C, A) , PD(C), PU(A) and S(A, B***)



**State\_1:** ON(B, A) Λ ONT(C)

* To satisfy ON(B, C), following operators are applied

***US(A, B) , PD(A), PU(B) and S(B, C)***

**State\_2:**  ON(B, C) Λ ONT(A)



* Finally satisfy combined goal ON(A, B) Λ ON(B, C).
* Combined goal fails as while satisfying ON(B, C), we have undone ON(A, B).
* Difference in goal and current state is ON(A, B).
* Operations required are PU(A) and S(A, B)



* The complete plan for solution is as follows:

1. US(C, A)

2. PD (C)

**3. PU(A)**

**4. S(A, B)**

**5. US(A, B)**

**6. PD(A)**

7. PU(B)

8. S(B, C)

9. PU(A)

10. S(A, B)

* Although this plan will achieve the desired goal, but it is not efficient.
* In order to get efficient plan, either repair this plan or use some other method.
* Repairing is done by looking at places where operations are done and undone immediately, such as S(A, B) and US(A, B).
* By removing them, we get

1. US(C, A)

2. PD (C)

3. PU(B)

4. S(B, C)

5. PU(A)

6. S(A, B)