# PROBLEM SOLVING FRAMEWORK WITHIN DECISION SUPPORT SYSTEMS

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Abstract: In the study of problems solving, cognitive psychologists had generalized it as a process of applying skills to overcome obstacles and constraints, so as to move from a given state to the desired goal state. In here, we look at where a line could be drawn to divide the process of problem solving into two sub-processes; a one-off, but cognitive demanding task for human to define the problem space, in terms of representation, and a routine search process, that could be undertaken by a machine, to search and select a solution within a defined solution space, so that to oversee its execution from start to finish to realize the goal.



## 1 INTRODUCTION

However smart a person might think of himself, cognitive psychologists, Bransford and alike, (Bransford & Stein, 1993), had shown that in the event of problem solving, we still walk through the process as follows:

1. Problem identification
2. Definition of problem
3. Constructing a strategic for problem solving
4. Organizing information about a problem
5. Allocation of resources
6. Monitoring problem solving
7. Evaluating problem solving

Although many people may not be aware of the process, and might even miss out on some of these stages unknowingly, especially the first two stages, the reality would eventually bring them to understand that the efforts and resources directed at a misguided target is unlikely to bring the results as expected.

Reflecting on the two decision support system projects currently underway; namely "Hospital Bed Management System", and "C$^3$I System for Bus Lane Management", we have observed that if the system developer could identify and define the problem in terms of some forms of representation, a decision support system could be put in place to search for a solution within the defined solution space, then the human and machine could have completed the problem solving cycle together to realize the goal, collectively.

## 2 WHAT IS A PROBLEM?

Medin and Ross (1997) considered a problem to have four aspects; ***goal***, ***givens***, ***means of transforming conditions***, and ***obstacles***.

The ***goal*** is some state of knowledge toward which the problem solving is directed and for which at least some criterion can be applied to assess whether the problem has been solved. The ***givens*** include the objects, ***conditions***, and ***constraints*** that are provided with the problem, either explicitly or implicitly. Problems need to have some ***means of transforming conditions***, of changing the initial state to the goal state. Finally, problems usually associated with some ***obstacles***.

In here, Medin and Ross described problem solving as a process

a) Starting from an initial state
b) Trying to arrive at the goal state
c) Solution is a path connecting the initial state to the goal state; along the way, using whatever mans and resources provided to transform conditions, and overcoming obstacles.

Medin and Ross also further divided the types of problems into Well-defined problems, and Ill-defined problems; the former as having completely


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specified ***initial conditions***, ***goals*** and ***means of transforming conditions***, while the latter have some aspects of the problem not completely specified. Nevertheless, H. A. Simon (1973) has argued that a crucial part of problem solving is changing an ill-defined problem into a well-defined problem (or often, a number of well defined problems).

## 3 PROBLEM-SOLVING CYCLE

Bransford, and Sternberg (1996) consolidated the problem solving sequence into a seven step cycle as stated in the Introduction Section; in which problem was identified and defined in Step 1 and 2, to provide the initial state and goal state for the generation of a path in Step 3, 4 and 5. However, in a dynamic environment, when all objects are constantly evolving, the chosen solution is unlike to run smoothly from start to finish without a hitch, some form of modifications would likely to take place so as to steer the course. Therefore, a problem solver should monitor and guide the solution towards the goal state, modify and repair it along the way. Finally, once arrived at the goal state, the problem solver should evaluate the results, and hopefully learn from the experience.

## 4 FRAMEWORK FOR PROBLEM SOLVING

By studying the process of problem solving by human; we examine the limitation of problem solving by machine, with the purpose of introducing machine intelligence into the process of problem solving.

Firstly, problem identification and definition are the two very demanding cognitive tasks that should be left with human being in the problem solving cycle, so that the problem solver could study the problem, focus on the problem, and define it in terms of goal, and objectives that it could be decomposed into.

Secondly, although monitoring problem solving in a dynamic environment is another demanding task, it is possible to develop a system framework for a machine to undertake this task to select a suitable strategic formations and tactical plans from a set of plans well defined plans kept inside the solution space, so as to steer the operational plan from start to finish.

Thirdly, if the construction of strategic formation could be combined with its tactical realization, and package together as one co-operative plan, then selection of the best possible plan could be based on not only the quality of strategic formation, but also the cost of realization as the criteria for plan selection.

Based on Sternberg (1996) 7 steps sequence, we put forward a problem solving framework that consolidated the problem solving cycle into a 4 stages operational procedure:

1. Deliberation;
2. Planning;
3. Plan Selection; and
4. Plan Realization.

**Deliberation:**

At the Deliberation stage,

- The system architect studies the current situation and identifies the desired situation by analyzing the situation map.
- The system architect performs mapping on the desired situation (qualitative goal) into a list of achievable (quantitative) objectives, which must be accomplished in order to realize the goal.
- The system architect evaluates the current situation and its feasibility in reaching all the intermediate states required in the desired formation either by case-based reasoning or planning.

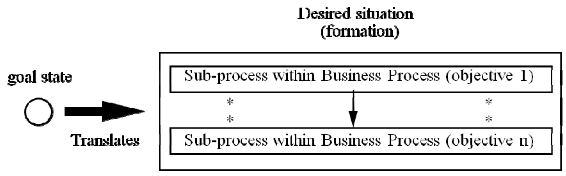


Figure 1: The process of translating goal into a strategic formation.

**Planning:**

During the Planning stage, the task is to develop strategic formations that connect all objectives identified together, as well as looking into the details of each objective to study the feasibility of their realization.

The main task for planning is to produce at least one fully connected solution paths in the form of a two stage co-operative plan

- Strategic Planning establishes the operational flows of the entire business process.
- Tactical planning to work out the physical

paths between states

- The distinction between strategic and tactical planning is essential here, as the former provides the overview of the plan from start to finish, while the latter would only generate paths between two states.
- Strategic Planning provides the formation based on the list of intermediate states, or achievable objectives (partial plan), sandwich between the initial and goal states.
- The eventual outcome of a strategic plan should be at least one operational plan that flows from the initial state to the desired goal state, stating the constraints and preconditions in each state, as well as the interlocking relationship between states (objectives), but without physical paths joining states together. As shown in Figure 4 below.

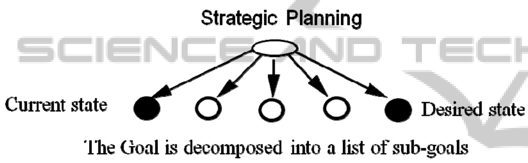


Figure 2: Strategic Planning is a process of decomposition.

- Tactical Planning is responsible for generating detailed paths to achieve the objectives in the formations.
- its approaches the problem from the lowest level of abstraction, formulating solution in the form of course of actions to move from one state to another, often without an overall picture (strategy) that includes the initial and desired goal states.
- It decision is based on short-term consideration to connect the two neighboring states under the guidance of some heuristics.

The framework for Co-operative Planning brings together the overview of the strategic formation (strategic planning), as well as the detail course-of-action for the realization of each objective. As shown in Figure 3.

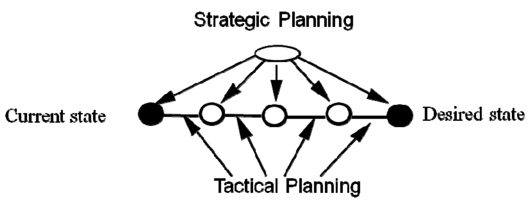


Figure 3: Framework for Co-operative Planning.

This two level Co-operative Planning process enhances the chances of the solution (work procedure) survive in a dynamic environment during plan realization.

- By focusing initially on strategic issue as a list of objectives, which have only pre- and post-condition, but without rigid physical paths between states. This enable changes in the strategic formation by simply adding and deleting objectives, without constraint of physical connection.
- Nevertheless, the plan will become rigid and inflexible once the paths between intermediate states have been at the tactically planning stage.

**Plan Selection**

The third stage is a decision-making procedure to select an operational plan, where all proposed solutions are compared based on some forms of selection mechanisms to resolve conflict among different plans.

- Each strategic plan once being merged and consolidated into a workable solution (workflow), its quality can be measured in terms of
  - cost, and
  - uncertainty,
- The most preferential solution path would be given priority as the operational plan, with other workable solutions being labeled as stand-by plans.

**Plan Realization**

At the final stage of the operational procedure, an operational manager will be put in place within the decision support system (DSS) to check and assess the progress of each process to ensure that the pre-programmed work procedure (workflow) remains relevant and cost-effective in the light of changes in the environment. With the framework of Co-operative planning, the Operational Manager could modify and repair at either the strategic or tactical level.

The roles of the DSS Operational Manager is

- to coordinate all required resources to achieve the ultimate goal.
- to repair the paths between intermediate states, or perform local re-planning, when the survival of operational plan is threaten
- to trigger stand-by plans, when operational plan becomes impossible

## 5 HOSPITAL BEDS MANAGEMENT SYSTEM

In a modern hospital, the management of hospital beds is an essential part of the in-patient workflow system, as it indicates not only the flows of in-coming patients into the wards, but also the resources and manpower required to support these patients using the beds. Therefore, the pattern of hospital bed usage is often used as a proxy to measure the number of patients treated in the hospital.

**Deliberation:**

Problem identification:

There is no central control to overseeing the release of beds for the admission of new patients.

Definition of problem:

Although a bed management system is installed at *Khoo Teck Puat Hospital* (*KTPH*), it is only a situation map to display the status of hospital beds usage in terms of R (Ready to use), or P (Prepare for discharge), but does not monitor the transition from "P" to "R". Hence, we define the goal as follows:

**Goal:** To monitor the realization and execution of the operational plan to transform from "P" to "R".

**Objectives:** Discharge (A, F, T, L) → C.

The goal could be decomposed into a list of objectives shown above. Patient discharges are often decided upon during the physician visit to the ward every morning. A list of activities followed thereafter must be completed before patients leave hospital; scheduling appointment (A), collecting prescriptions (F), arranging family member to take them home (T), collecting letter from the doctor who decide to discharge them (L). These activities are not sequential, and therefore could be executed in parallel. Once the bed is freed, the bed should be cleaned (C) before the status changes from "P" to "R". In theory, cleaning process could take place in parallel with Discharge (A, F, T, L) provided the discharged patient could be moved off the bed into a discharge lounge, where patients could rest and wait in the lounge for the completion of "A", "F", "T" and "L".

**Planning:**

Show in the situation map, the existing bed management system indicates the number of "P" and the number of "R" on the screen, to indicate the status of patient admission into the wards. The execution of the course of actions for Discharge (A, F, T, L) are undertaken outside the system, only when "P" is transformed into "R" status would the status be displayed onto the system.

To speed up the transformation from "P" to "R", tactical planning for "A", "F", "T" and "L" will be formulated as part of the co-cooperative plan.

**Co-operative plan 1**

Strategic Plan 1: Discharge (D Lounge) → C → R

Tactical Pan 1: If patient is well enough to be send home, discharge to the Discharge Lounge, would enable the bed to be cleaned, and proceed to turning the status of bed from "P" to "R".

**Co-operative plan 2**

Strategic Plan 2: Discharge (A, F, T, L) → C → R

Tactical Plan 2: However, if the patient is not well enough to be moved off the bed, the completion of "A", "F", "T", and "L" will be the precondition to proceed to cleaning the bed "C". This will become the task for DSS operational manage to monitor and execution during the plan realization stage.

Co-operative plan 1 and Co-operation plan 2 are the alternative realization for the same goal to transform from "P" to "R".

**Plan Selection:**

Different sets of Co-operative plan will be studied and compared for the selection of the best plan as the operational plans, leaving the rest of the plans as stand-by plans.

**Plan Realization:**

One of the strength of Co-operative planning is in its ability to repair or change plan during execution in respond to changes in environment; either strategically, or tactically. For instance, if status "F" have not completed within a predetermined time, alert will be sent to pharmacy to look into the matter. Same is applicable to "L" status, if letter from doctor is unable to be completed in time, then alternatively solution such as sending it by email, or post, could be activated. The role of DSS operational manager is to study and monitor to ensure the operational plan is successfully executed.

In summary, the operational procedure of the KTPH bed management system consists of 4 stages:

1. **Deliberation:**
   **A** Dashboard or Situation Map will consolidate information about bed status to be displayed onto the nurse station in the wards, and the A&E department.

2. **Planning:**
   A number of Co-operative plans would be studied and put forward for consideration
3. **Plan Selection:**
   Assume that Co-operative Plan 1 had been selected as operational plan. Co-operative Plan 2 will become the stand-by plan.
4. **Plan Realization:**
   In the event of operational plan become impossible to move patient into the Discharge Lounge, the DSS operational manager could switch over to one of the stand-by plan, such as Co-operative Plan 2 to complete the Discharge (A, F, T, L) before cleaning the bed.

In reflection, we consider the hospital beds management system as a well-defined problem with very little uncertainty, therefore, we could walked through the process of problem solving cycle, by dedicating the first two stages to the system architect, and leaving the plan selection and realization phases to the decision support system to take care of.

1. **Deliberation;** untaken by system architect
2. **Planning:** untaken by system architect
3. **Plan Selection:** untaken by the system
4. **Plan Realization:** untaken by the system

In here, only case-based reasoning approach is required to search through the solution space stored in the case-based library for managing the bed usage in the hospital.

There is no need to deploy planning approach to construct solutions backward from the goal state, or forward from the current state. Nevertheless, in order to demonstrate the potential of our problem solving framework, we have included a different set of Co-operative plan in the event of national emergency when the hospital was overwhelmed by hundred of patients coming through the A&E department.

**Deliberation:**

Problem identification:

There is no central control to overseeing the release of beds for the admission of new patients.

Definition of problem:

In order to increase the number of patients admitted, we now defined the problem by means of beds available within the whole KTPH, and not by number of beds inside the wards. In other words, beds could be placed anywhere along the hospital corridors, so that to increase the intake of patients.

The Goal: to search for spaces to accommodate the extra beds outside the wards.

Objectives: to pack maximum number of beds in the designated areas (DA).

**Planning:**

Assuming the hospital has sufficient space to accommodate all the extra beds needed to cope with the situation. One of the strategic plans could be

**Co-operative plan N**

Strategic Plan n:

Extra capacity = $DA^1 + DA^2 + \ldots\ldots DA^n$

Tactical Pan m:

Searching extra beds for $DA^1$; +

::::::::::::::::::::::::::::::::::::::::::

Searching extra beds for $DA^n$

Logistically, in order to realize the tracking of moving objects (beds) moving around the hospital, each bed would be fitted with a wireless tag, so that its movement could be tracked and status displayed on the dashboard or situation map.

## 6 BUS LANE MANAGEMENT SYSTEMS

The bus lane scheme in Singapore was launched in 1974, to give buses priority to travel along special destined bus lane on the roads, so that to enter and exit bus stops without the obstruction.

Subsequently, the Land Transport Authority (LTA) of Singapore launched a full-day bus lane scheme in 2005 along Orchard Road to improve bus travelling speeds, with the purpose of encouraging shoppers to use public transport, rather than taking onto their cars. In December 2008, it was Estimated that there were a total of 23km of full-day bus lanes and 155km of normal bus lanes in Singapore.

This project is funded by the National Research Foundation of Singapore.

**Deliberation:**

Problem identification:

Vehicles other than buses are obstructing buses travelling on the roads.

Definition of problem:

To detect and identify the vehicle intruding into the designated bus lanes; and record down the evidence of violation legally *admissible* in court.

The Goal: to detect and identify the vehicle intruding into designated bus lanes.

| | |
|---|---|
| Objectives: | Obj1 is to detect the vehicle into the bus lanes; (Using scanners and overview camera)<br>Obj2 is to identify the type of vehicle, and its number plate; (Using a front and a rear camera)<br>Obj3 is to record down the sequence of violation with time stamp, which could be legally *admissible* in court. (Using an overview camera)<br>Obj4 is to transmit the data to the backend system (LTA office) by means of wireless technology. |

**Planning:**
One of the strategic plans could be

Strategic Plan 1: Obj1 + Obj2 + Obj3 + Obj4

| | |
|---|---|
| Tactical Pan for Obj1 | Detect vehicle into bus lane within the 50m range before the bus stop, trigger the activation of the front and rear cameras, plus nIR lighting if needed. |
| Tactical Pan for Obj2: | capture and read the vehicle licence plates (including front and rear views) and vehicle classification. |
| Tactical Pan for Obj3: | record sequence of vehicle(s) violation footage inside the bus lanes. |
| Tactical Pan for Obj4: | processed all the information required on-site, before transmitting them to the back office by wireless. |

**Plan Selection:**

There will be different sets of strategic plan for different scenarios; in a normal scenario, the vehicle licence plates are clearly recognisable, but in other situations where vehicle licence plates could not be positively identified. In such cases, a different Co-operative plan might have to be activated to identify the vehicle involved, such as checking inside the database for profile of the vehicles resemble the one in question that might have been captured by the system earlier. In this case, features of this vehicle in question, other than licence plates could be used to help to identify the vehicle. Based on the assumption that people always making the same journey when travelling from one place to the other.

Different tactical plans are also kept n place to support classification of vehicle, by means of colour detection, license plate colour detection, type of vehicles.

**Plan Realization:**
In order to cope with every kind of situations on the roads, the role of the DSS operational manager is to steer the operation to achieve the objectives set out in the strategic plan, and realize the goal by detect, identify, capture, and transmit the violation of bus land back to the back office.

In comparison with the hospital bed management system, the bus lane management system is also a well-defined problem with changes in environment, and quality of pattern recognition on the licence plates being the uncertainty, we, therefore, also dedicated the first two stages to the system architect, and the plan selection and realization tasks to the DSS operational manager.

1. **Deliberation;** untaken by system architect
2. **Planning:** untaken by system architect
3. **Plan Selection:** untaken by the system
4. **Plan Realization:** untaken by the system

Once identified, and defined, all possible scenarios are studied to develop solutions to cope with the situations, with representation of each solution kept inside the case-based library, so that, DSS operational manager could select, and activate the operational plan to detect and identify the vehicle intruding into designated bus lanes. If successful, LTA of Singapore will consider doing away with civil contractors to police bus lane to enforce violation.

# 7 CONCLUSIONS

The framework for problem solving put forward in this paper has been applied to the two DSS projects presented above with encouraging results; the two level co-operative planning has provided the flexibility for the decision support system to repair and modify the operational plan during execution, supported with stand-by plans available in the solution space.

The difficulty with searching for problem space is that the number of possibility is often too large to try them all. The problem solving framework we proposed here, provides a sound partition of work between the system developer, and the DSS operational manager to enable them to complete the problem solving cycle co-operatively and collectively; each focus on what they do best; human developers take on the most cognitive demanding task in deliberation and planning so as to define a solution space, focus on only a limited sets of solutions for the machine to select, while the DSS operational manager would perform the routine tasks of plan selection and execution; selecting the most appropriate plan as operational plan, and steer it to achieve the objective, and realize the goal. Hence, the framework for problem solving we put forward here reinforces Newell and Simon's view that problem solving as representation and search. The steps for deliberation and planning focus on issues of identifying problem, defining problem into a set of representations that is sufficient to cover the problem space, yet small enough for machine to search for solution, and realize it. (Newell & Simon, 1972)

Representation:

1. **Deliberation;** untaken by system architect
2. **Planning:** untaken by system architect

Search:

3. **Plan Selection:** untaken by the system
4. **Plan Realization:** untaken by the system

In conclusion, the two decision support systems undertaken are domain dependent and well defined, with only a limited set of scenarios to cover. Therefore, at this moment in time, we could idealize the solution space as a closed solution space with a set of well defined solutions of problem stored in the knowledge base. However, as H. A. Simon (1973) put it "a crucial part of problem solving is changing an ill-defined problem into a well-defined problem (or often, a number of well defined problems)." Given time, when we are able to build or granted access to sufficient number of well-defined problems, we would be in the position to develop methodology to solve ill-defined problems.

The development of **Evidence-based medicine** (EBM) is one step along this direction.

> "The conscious, explicit and judicious use of the **best current evidence** in making decisions about the individual patients."
>
> (Sackett et al., 1996)

The so called best current evidences are patient case notes of certain disease kept in the databases of some EBM centres. One day, in a not too distance future, we, as doctors, could use a list of symptoms associated with a particular disease as search keys to locate a summary of these patient case note stored in databases around the world, to help us in our diagnosis for some unknown or ill-defined disease. With the connectivity of internet today, it should not be too far in the future to realize this dream.

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