# Influence diagram and Decision tree

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**Introduction**

Decision trees and influence diagrams can be extremely useful in helping people to gain an understanding of the structure of the problems which confront them.

Decision trees can serve a number of purposes when complex multi-stage problems are encountered. They can help a decision maker to develop a clear view of the structure of a problem and make it easier to determine the possible scenarios which can result if a particular course of action is chosen. It can also help a decision maker to judge the nature of the information which can result if a particular course of action is chosen. It can also help a decision maker to judge the nature of the information which needs to be gathered in order to tackle a problem and, because they are generally easy to understand, they can be an excellent medium for communicating one’s perception of a problem to other individuals. Influence diagrams offer an alternative way of structuring a complex decision problem and some analysts find that people relate to them much more easily, and it can be converted to decision trees.

**Influence Diagram**

Influence Diagram is designed to summarize the dependencies that are seen to exist among events and acts within a decision. Such dependencies may be mediated by the flow of time.

**Symbol**

Things used to describe the decision problem:
1. **Nodes**
   - There are three distinct types of nodes: Decision, Circular and Diamond nodes.
2. **Directed arcs**
   - Used to denote possible conditional dependence in influence diagrams.

The symbol and the meaning of nodes and arcs are shown below:

- **Decision nodes**
  - Represent decision

- **Circular nodes**
  - Random quantities or event (uncertain event)

- **Diamond nodes**
  - Result of decision problem

- **Directed arcs**
  - Influence
Example:

For (a)
A directed arc joins two chance nodes that represent the random events X and Y. The outcome of the random event X will be known when the probability distribution of Y is assessed.

For (b)
The directed arc that joins chance node X to decision node D indicates the value of X may influence the decision D.

For (c)
The directed arc that joins decision node D to chance node X indicates that the decision D is made before the random event X occurs.

For (d)
The directed arc that connects two decision node D1 and D2 indicates that the decision selected for D1 is known to the decision maker before D2 is made.

For (e)
The directed arc indicates that the result R of the decision process depends on the outcome of the random event X.

For (f)
R depends on the decision alternative chosen.
Influence diagram and Decision tree

After knowing the basic structure of the influence diagram, it is a high time to introduce how to construct a diagram.

**Formulation:**

1. Start with a preliminary list of the decisions, random events or random quantities and possible outcome. Identify the attributes and objective that will be used to measure the result.
2. For decision and random event: give a clear name, definition, and measurement units.
3. Random quantity with round nodes; decision with square node. Draw them in time order of occurrence from left to right.
4. Identify any influences or dependencies between random quantities and decisions.
5. Check to see there are no directed cycles in your diagram.
6. To check the diagram so that it fulfills the principle of coherence.

**Tips:**
1. Draw alternative diagrams if you unsure the one constructed.
2. Assume conditional independence rather than conditional dependence if you are unsure.
3. Keep the formulation as simple as possible.
4. Better work together with decision maker to formulate the problem correctly.

**Illustration:**

**The problem of Coach’s decision:**

**Background:**
Suppose a American football team has just scored with less than a minute remaining, and the score now is 16 to 17. Your must decide whether to try for the one-point kick conversion that, if successful, would tie the game with no time left to win, or attempt a two-point kick conversion and possibly win the game.

**Formulation**

1. **State the nodes**
   - We define one decision node, D, one chance node and one diamond node.

   ![Diagram](attachment:diagram.png)

   - Play outcome
   - Coach’s decision
   - Outcome of the game

2. The random variable X that takes the value of 1 or 0
   - The result takes the win, lose or tie.
   - The D takes one-point kick or two point-point kick conversion.

3-6. The node from D to R:
   - There is an arrow from D to R as when the decision maker makes decision, it will affect the outcome. For example, if the decision maker decides to choose one-point tick conversion, the result is tie or lose; otherwise, if the decision maker decides to choose two-point tick conversion, the result will be win or lose.
Influence diagram and Decision tree

The node from D to X:

If we believe that there is a higher probability of scoring from a one-point kick conversion, the coach’s decision influences the probability distribution associated with the chance node.

After following the formulation rule, an influence diagram has been obtained below:

Coach’s decision
on the play

**Influence diagram for the football problem**
Comparison between Influence diagram and Decision tree

Influence diagrams and decision trees play an important joint role in the interactive process of building, testing decision models and deriving solution. Both Approaches are complementary relationship. The major difference between them is that influence diagram provide framework for people to discuss problem structure and dependencies without involving mathematical notation. Second, it reduces a large volume of data and more easily revised as the decision maker iterates

The difference between influence diagram and decision tree summarized as below:

<table>
<thead>
<tr>
<th>Model features</th>
<th>Influence Diagram</th>
<th>Decision tree</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timing</strong></td>
<td>Both show timing of all decisions and uncertain events.</td>
<td>Dependence among uncertain events but decisions not shown.</td>
</tr>
<tr>
<td><strong>Conditional independence</strong></td>
<td>Shows dependence among uncertain events and decisions.</td>
<td></td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>Number of nodes grows linearly with the number of variables.</td>
<td>Number of terminal nodes and paths grows exponentially with the number of variables</td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>Identifies dependencies of variables without need for data.</td>
<td>Decision, probability and result data shown explicitly.</td>
</tr>
<tr>
<td><strong>Variable type</strong></td>
<td>Both continuous and discrete decisions and probabilities.</td>
<td>Adequate only for discrete variables.</td>
</tr>
<tr>
<td><strong>Asymmetry</strong></td>
<td>Scenarios with different event sequences not distinguished.</td>
<td>Shows asymmetric structure of problem.</td>
</tr>
<tr>
<td><strong>Modeling usefulness</strong></td>
<td>Most useful in initial states of modeling</td>
<td>Useful in depicting detailed uncertain event outcomes and decisions, and model solution.</td>
</tr>
<tr>
<td><strong>Captures interaction between decision maker and analyst</strong></td>
<td></td>
<td>Difficult to display large problems.</td>
</tr>
<tr>
<td><strong>Bayes’ Rule</strong></td>
<td>Indicated by arc reversal, but calculation not show</td>
<td>Indicated by node reversal (a separate event tree may be used as an aid for calculation).</td>
</tr>
<tr>
<td><strong>Reduction Method</strong></td>
<td>Reduction by a set of reduction operations possible using various algorithms.</td>
<td>Uses simple rollback algorithm</td>
</tr>
</tbody>
</table>
Turning an Influence diagram into a decision tree:

Obviously, a decision tree representation must preserve the ordering represented by the arrows in an influence diagram and the tree must not have an event node as a predecessor of a decision node for which it is not directly linked by an arrow in the influence diagram. If the tree did, it would imply that the decision depends on the event node which, from the influence diagram, is not the case.

Procedure for turning an influence diagram into a decision tree:

1. Identify a node with no arrows pointing into it (since there can be no loops at least one node will be such).
2. If there is a choice between a decision node and an event node, choose the decision node.
3. Place the node at the beginning of the tree and ‘remove’ the node from the influence diagram.
4. For the now-reduced diagram, choose another node with no arrows pointing into it. If there is a choice a decision node should be chosen.
5. Place this node next in the tree and ‘remove’ it from the influence diagram.
6. Repeat the above procedure until all the nodes have been removed from the influence diagram.

Problem solving

ABC Chemicals are planning to start manufacturing a new pharmaceutical product. Initially, they must decide whether to go for large-scale or small-scale production. Having made this decision, the profits that they make will also depend on:

(i) The state of the economy over the next two years
(ii) Whether or not a rival manufacturer launches a similar product
(iii) The amount which ABC decides to spend on advertising the product (this decision will itself be influenced by the scale of production which ABC opt for, whether a rival product is launched and the state of the economy)

D1: Decision to go for large-scale or small-scale production
E1: State of economy over the next two years
E2: Whether there is rival manufacturer launching a similar product
D2: Amount of advertising the product
R: Profits
Influence diagram and Decision tree

The influence diagram:

- **D1**: Go for large-scale or small-scale production
- **E1**: State of economy over the next two years
- **E2**: Whether rival manufacturer launches similar product or not
- **D2**: Amount of advertising
- **R**: Profits

Assumption:
1. State of economy over the next two years does not depend on the scale of production decided to go for.
2. Rival manufacturer launching similar product does not depend on the scale of production decided to go for.
3. State of economy over the next two years and rival manufacturer launching similar product is independent.
Using influence diagram to derive the decision tree:

**Explanation:**
From the influence diagram, we choose one node without arrows pointing to it. D1 is the starting node of decision tree since it is a decision node, and then it is removed from the influence diagram. Next, there are two event nodes without arrows pointing to them, that is, E1 and E2. We choose E1 first and E2 next, and they are removed from the influence diagram. D2 is the next node to be chosen, and R follows D2, both of them are removed from the influence diagram. The decision tree is completed when all nodes in the influence diagram are removed.
New Concept on Decision Tree:

Extended Pearson – Tukey (EP-T) Approximation:
In some decision problem, decision maker may find that the number of possible outcomes may be very large or even infinite. These variable could be represented by continuous probability distributions. There is a method to incorporate such distributions into our decision tree format is called the “Extended Pearson – Tukey (EP-T) Approximation”. This method is based on earlier work by Pearson and Tukey (an Approximating Means and Standard Deviations Based on Distances between Percentage Points of Frequency Curves), and requires three estimates to be made by the decision maker:
(1) The value in the distribution which has a 95% chance of being exceeded. This value is allocated a probability of 0.185.
(2) The value in the distribution which has a 50% chance of being exceeded. This value is allocated a probability of 0.63.
(3) The value in the distribution which has only a 5% chance of being exceeded. This value is allocated a probability of 0.185.

Example of EP-T approximation:
Suppose that a marketing manager has to decide whether to launch a new product and wishes to represent on a decision tree the possible sales levels which will be achieved in the first year if the product is launched. To apply the EP-T approximation to the sales probability distribution we would need to obtain the three estimates from the decision maker. Suppose that she estimates that there is a 95% chance that first-year sales will exceed 10000 units, a 50% chance that they will exceed 15000 units and a 5% chance they will exceed 25000 units. The resulting decision tree is shown in Fig 3a, while Fig 3b illustrates how the discrete distribution has been used to approximate the continuous distribution.
Influence diagram and Decision tree

(Fig 3a)

First-year sales

10,000 units sold
0.185

15,000 units sold
0.63

25,000 units sold
0.185

Launch product

Do not launch product

(Fig 3b)

Discrete distribution

Continuous distribution

% 0.7

0.6

0.5

0.4

0.3

0.2

0.1

0

10,000 15,000 20,000 25,000
Conclusion

Influence diagrams are greatly aid in problem formulation and can be used to visualize the structure and interpret the results of decision problems. Both approaches, decision tree and influence diagram, have their advantages and disadvantage and we can conclude that both approaches are complementary relationship.

References

3. Internet resources: 
   http://www.lapietra.edu/jkros/articles/infludia.htm

Final Mark  81/100