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Decision-making under Uncertainty using Point-Cloud

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Introduction

A point-cloud is a visual representation of variability and modality of an uncertain variable. Ullah and his colleagues [1,2] have worked out a decision-making framework where a point-cloud plays the central role. This editorial describes some salient points of the point-could base decision-making. With this the study describes a method for dealing with design decision making under uncertainty using point-cloud.

The concept of point-cloud

This section describes the concept of point-cloud in visualizing the uncertainty associated with a variable.

Let V be a variable and V (t) ∈ R, t=0,1,..., be its random states determined by Monte Carlo simulation or by any other means. The two dimension representation of the states of V using the ordered-pair (V(t),V(t+i)) (i is a small integer, i ∈{1,2,...}) is its point-cloud. In its simplest form, we use i=1. The point-cloud is a visual means for comprehending the modality and variability in V. To understand this, consider four cases, as follows:

(a) V=50 (i.e., a constant value equal to 50)

(b) V ∈ {40, 50, 60} (a crisp value either 40, 50, or 60)

(c) V ∈ [40,60] (a value in the interval 40 to 60)

(d) V ∈ N(50,5) (a normally distributed variable with mean 50 and standard deviation 5)

The point-clouds corresponding to the cases (a)-(d) are shown by four plots labeled (a)-(d), respectively, as shown in Figure 1.

First, consider the point-cloud (a) in Figure 1. It is rather a point (50, 50) representing the fact that the variable does not possess any uncertainty. The second point-cloud (b) is a collection points nine (3·3=9) points (x,y), ∀x,∀y ∈ {40,50,60} reflecting the fact that the variable takes values from {40, 50, 60} at random. The third point-cloud (c) looks like a square-box wherein the vertices are (40, 40), (60, 40), (60, 60) and (40, 60) (in the anti-clockwise direction) reflecting the fact that the variable takes values in the interval [40,60] at random. The last point-cloud (d) looks like a circle and the points cluster around the mean 50 where the spread depends on the standard deviation 5 (the point-cloud could have been scattered much if the standard deviation were greater than 5). Note that for the cases (b), (c), and (d), Monte Carlo simulation is used to generate the points V(t), t=0,1,.... In particular, Monte Carlo simulation of discrete events is used and for the cases (c)-(d) the procedures for simulating continues variables that follow uniform distribution and normal distribution, respectively, are used.

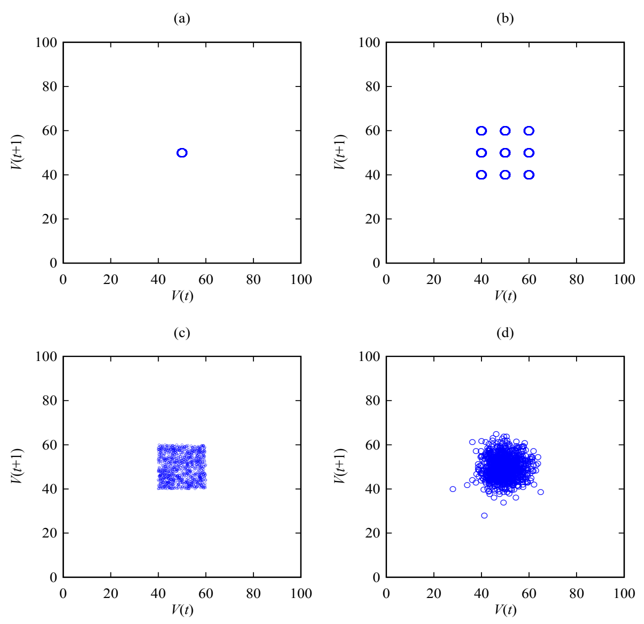

Figure 1: Examples of point-clouds.

This way the point-cloud provides a visual means that helps comprehend the variability and modality of an uncertain (certain) variable, and thereby, helps determine the course of action of a human decision maker.

Decision-making framework

The decision-making framework using point-cloud (explained in the previous section) has been explained in [1,2] in a rigorous way. This section highlights the salient points in a lucid manner.

The decision-making framework is schematically illustrated in Figure 2. As seen from Figure 2, the framework starts by defining a piece of Analytical Knowledge (AK) consisting of a set of analytical relationships, F1, F2,…, i.e., AK={F1, F2,…}. One can identify some of the parameters pertaining to AK as Requirement Parameters: RP1, RP2,…. These parameters are used to set the requirements of a decision-making problem. Simultaneously, some other parameters can be identified as Solution Parameters: SP1, SP2,…. These parameters are used to suggest a plausible solution for solving the decision-making problem. As such, AK |= RP1, RP2,…,SP1, SP2,… and {RP1, RP2,...} ∩ {SP1, SP2,...}=∅.

In addition, the analytical relationships F1, F2,… can be rearranged to formulate two variables called Requirement Variable (RV=f(RP1,PR2,…)) and Solution Variable (SV=g(SP1,SP2,…)) so that RV=SV. This means that the point-clouds of RV and SV must be two overlapping point-clouds. Otherwise, SV is not good enough in

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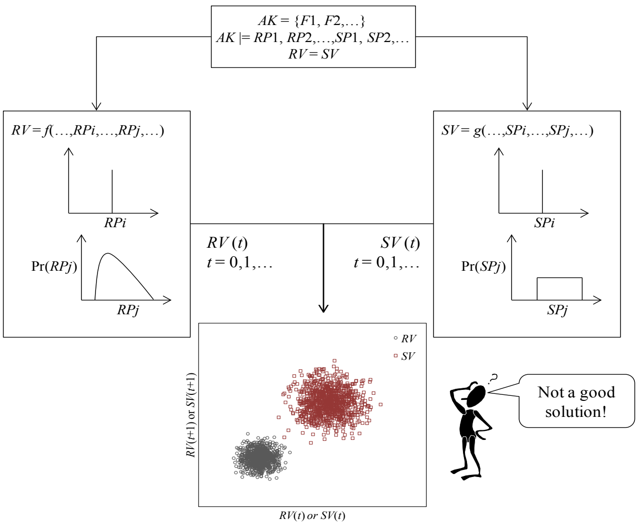

Figure 2: The proposed design decision framework.

fulfilling RV. The arbitrary case shown in Figure 2 is a case where the point-cloud of SV is far from the point-cloud of RV, elucidating the fact that the underlying solution (defined by SV) does not fulfill the requirement (defined by RV) ("RV=SV" does not hold, as such, if the proposed solution is adopted). Therefore, the underlying solution must be discarded and other new solutions should be considered toward having more satisfactory results. This way one can make a decision by visually inspecting the point-clouds of RV and SV and avoiding tedious calculations.

It is worth mentioning that the random states of RV and SV, denoted by RV(t) and SV(t), t=0,1,..., are generated by Mont Carlo simulation based on the respective models of the Requirement Parameters RPs and SPs. In Figure 2, RPi or SPi represents a parameter having no uncertainty and RPj or SPj represents another parameter having a certain degree of uncertainty modeled by a probability distribution (or by some other means).

Applications

The point-cloud based decision-making framework has been implemented to solve real-life decision-making problem. Khozaimy et al. [1] demonstrated that point-cloud based decision-making approach can help find a solution (an optimal mixture of public and private transportations) minimizing the CO^2 emissions generated by vehicles at a given geographical location. Ullah and Shamsuzzaman [2] have shown how to solve a complex design problem (select the optimal combination of two different materials for bimetallic thermostat) where all design variables (RV and SV) are subjected to a certain degree of uncertainty. One of the remarkable features of point-cloud is that it underlies both probability distribution and possibility distribution (i.e., fuzzy number).

Conclusion

As decision making information underlies a great deal of uncertainty, the use of the visual tool such as the point-cloud will help achieve more user-friendly decision making tools for the years to come.

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