Decisions of the 3rd Kind

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Insight: Special Issue; Systems of the 3rd Kind, July 2012, Volume 15, Issue 2, pp 21

System design is the evolution of information punctuated by decisions, decisions that are based on uncertain and evolving estimates from agents, web searches, simulations, tests, experience, or wild guesses; all tempered by conflicting human values, estimates and beliefs. The uncertainty creates risks with every decision made, regardless of whether the decision is focused on the architecture of the system, the relationships of the sub-systems, or the configuration of code, parts and assemblies in the sub-systems.

In this essay, I will discuss four "Kinds" of decisions. Decisions of the 0th Kind are informal, based on intuition or single point analysis. Decisions of the 1st Kind use a structure to help explore the decision-space and then test the results to investigate uncertainty. Those of the 2nd Kind are built on the assumption that uncertainty is a variable that permeates all information, not an after-thought. Finally, Decisions of the 3rd Kind are adaptive, fusing man and machine, understanding the current situation and past decisions in context, and tracking the inherent risks faced in the current situation. All four types will be developed here, but in practice most decisions are made using 0th Kind logic; mature organizations utilize the 1st Kind for major decisions; few use the 2nd, and the 3rd is glimpse into the future.

Nutt (2002), in a study of 400 decisions made by senior managers in medium-to-large organizations, found that fully half the decisions had failed—either action was not taken; or if taken, it did not stick. Of the decisions that failed, the only effect observed two years later was used resources—time, money, personnel, equipment, etc.—all expended without achieving success in attaining the original goals. According to the study's author, there were three main classes of "blunders" that doom decisions: 1) the use failure-prone practices (he saw this in two out of every three decisions he studied); 2) premature commitments (decision makers jump on the first idea that comes up and then justify it); and 3) people spend time and money on the wrong things (i.e. tasks that do not add value to making the best possible decision).

In another recent study, 2207 executives were queried about decision-making in their organizations; only 28% said that the quality of strategic decisions in their companies was generally good. Sixty percent thought that bad decisions were about as frequent as good ones, and the remaining 12% thought good decisions were infrequent.

There are many other studies showing similar results with business and technical decisions. They all beg the questions: 1) Why is successful decision-making so hard? and 2) Can computer environments help in reducing the risks (i.e. lower the probability of a failed decision) and hopefully lead to improvements in the decision success rate?

Answers to these begin with the Information Pyramid (Figure 1) (Ullman 2006, 30). At the base of the pyramid, the simplest form of information is raw data, text, or other factual information typically found in documents and databases. Working up the pyramid, models define relationships among data be they mental models or sophisticated analytical models. To gain knowledge you must understand and interpret the behavior of models. When your knowledge is sufficient, you can make decisions using judgment based on this knowledge. According to this Pyramid, the most valuable type of information, a decision, is based on all the less-valuable information types. In other words, supporting decision making requires the management of data, models, and knowledge, as well as the associated judgment upon which the decisions are based. This model applies at every level of systems development all the way from architecture to the smallest detail of a component feature.

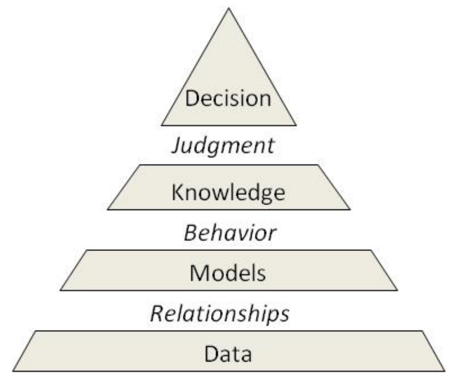

Figure 1. The Information Pyramid

Four factors complicate the Pyramid: 1) Computers are very good with data and models and but so far have only shown limited success with judgment and decisions. Judgments and decisions are still mainly the domain of people. 2) For most issues, the decision needs the knowledge and buy-in of multiple people. 3) Most decisions require projections into the uncertain future. They are not made on facts, but estimates and beliefs about events and conditions that are yet to happen. While accurate forecasts can be made in some limited areas, for most business and technical situations uncertainty and thus risks are very important. 4), in systems development, there are many interrelated issues needing decisions happening at the same time. The alternatives being considered for one issue pose constraints on other issues.

Risk occurs at each level in the Pyramid: the data and/or judgment may be poor, uncertain, conflicting, or missing); the fidelity of the models used may not be perfect; the knowledge gained from interpretation of the models or experience may be lacking. However, we commonly only do risk analysis after the system is defined and we do not well associate it with each level in the pyramid.

In tying these thoughts to the theme of this special issue, consider Figure 2 which shows the key features of each decision "Kind".

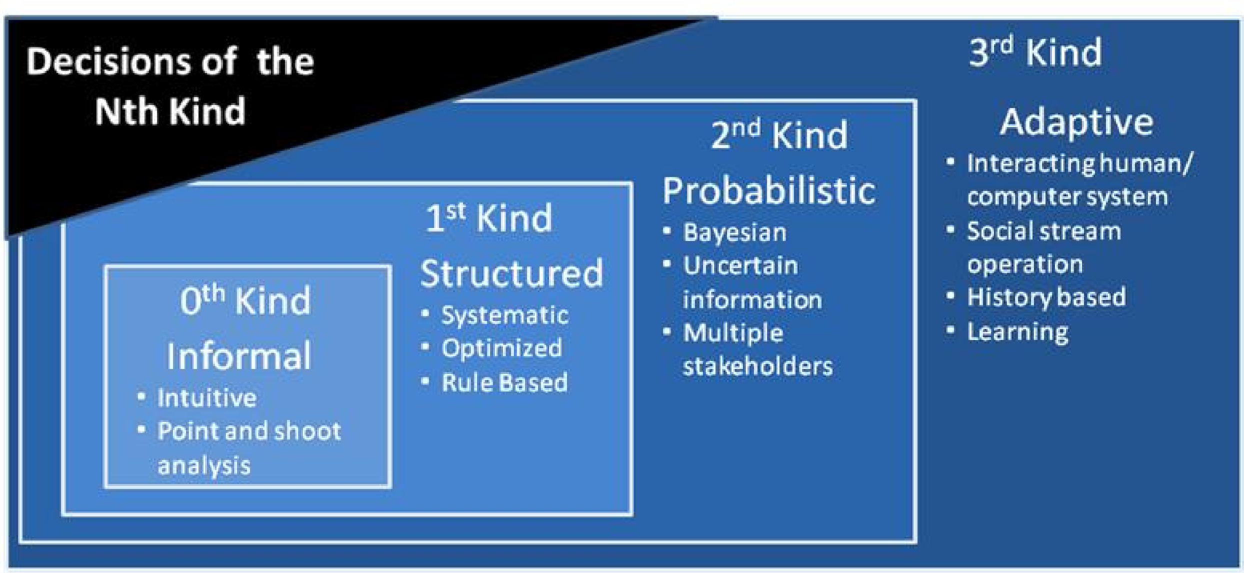

Figure 2. Decisions of the Nth kind

Decisions of the 0^{th} Kind – Informal

A study by one of my graduate students in the late 1980s included audio and video recordings of individual engineers designing products; then dissecting these recording on an utterance and sketch line-by-line basis (Stauffer and Ullman 1991). One finding of this study was that, at their finest level of granularity, decisions occur about once per minute. This is keeping with human's cognitive limitations and the generally accepted understanding that, in order to solve problems and make decisions we must divide them into very small pieces, address each one and then fuse the results together. Further, this study found that 30% of the decisions made were of an intuitive type (choice based on prior knowledge); 23% of design decisions were rule based (if this situation occurs, then do that); and the remaining 47% used a structured decision process (see Kind 1).

The 30% intuitive decisions were of the 0^{th} Kind, and there has recently been a recent spate of best-selling books that support the notion - go with your gut when making a decision. Intuitive decisions are based on prior knowledge and experience and don't need justification (if you are right). In terms of the Information Pyramid, knowledge is the instantiation and cognitive reduction of all germane models and data. Although the intuitive literature authors suggest that technical and business decisions can and should be made based on intuition, in actuality intuition is only a good approach when one person is responsible for the decision, his/her knowledge is high, time is too short to do anything structured or the consequences of a poor decision are low. If outside these constraints, making decisions based solely on intuition is generally a failure-prone practice.

A second permutation of 0^{th} Kind decisions is what I call point and shoot analysis. This is intuition with analytical support. It is common in systems engineering to pick the best guess and analyze it to make sure it meets the design needs. If it does, then choose it and move to the next issue. If not then try some other point in the design space, an informal type of optimization. This can result in a random walk until some workable solution is found (or not). But there is little guarantee that the solution is in any way optimal, it is only an option that works and that is good enough.

Generally Decisions of 0^{th} kind are not recorded in any reusable manner. While the resulting decision may fail or succeed, the route to get there is lost and can not be reused.

Decisions of the 1st Kind - Structured

Decisions of the 1^{st} kind are made with some type of basic structure to choose amongst multiple alternative courses of action. There are three sub-Kinds: systematic, optimized, and rule-based decisions. All are characterized by having multiple alternatives and some form of structured analysis to choose amongst them.

For systematic decisions, there are six basic steps, used iteratively: 1) Identify alternatives; 2) Develop measures or criteria; 3) Capture stakeholder values; 4) Evaluate the alternatives relative to the criteria; 5) Fuse the evaluations, and 6) Decide what to do next (Ullman 2006, 32). These are the basic steps taught by companies like Kepner-Tregoe and embodied, for the most part, in Decision Matrix or Pugh's Method (Ullman 2010). Using these steps formally or informally, begins to off-set the blunders identified in the introduction. However, where decisions of the 0^{th} Kind are human nature, decisions of the 1st Kind (and subsequent Kinds) must be taught, taking a conscious effort to execute them.

The need for more structured decisions has been realized by the U.S. Government. In reacting to high cost and schedule over-runs, the Department of Defense (DoD) and other agencies have begun using a method referred to as Analysis of Alternatives (AoA) which requires the development of multiple alternatives and analysis very early on for cost and other measures of effectiveness, complete with the analysis of risk. In 2009 the GAO was tasked with studying how well AoA efforts ensured that DoD projects met time and cost targets (Ullman D. G. and R. Ast 2010). They studied 22 major systems acquisition projects. Thirteen had a “Narrow Scope of Alternatives”, of these, only 31% resulted in low cost and schedule growth. The remainder had high growth. Meanwhile the nine that included a “Broad Scope of Alternatives” resulted in 78% with low cost and schedule growth.

A second form of 1st Kind decision relies on formal, analytical optimization. The alternatives are the design space and the criteria are the analytical constraints. For most systems the fidelity of the models is just too low; there are qualitative factors that can’t be modeled; there is too much uncertainty (see decisions of the 2nd Kind); or there is too little time to formally optimize. Only a few industries are mature enough in which formal optimization is a major contributor.

In some situations the decision making process can be reduced to set of if-then rules (Taylor 2012). This is only true when the system is very well known, uncertainty is low and there are not multiple, potentially conflicting sources of information. In this situation the six steps are rolled into rules that embody all the elements of the Information Pyramid and generate decisions.

Most higher education does not even cover the six basics steps and most companies do not practice decisions of the 1st Kind. Rather, they justify that 0th Kind decisions are good enough and move on with little regard to uncertainties, risks and the quality of their decision-making. The common excuse is “there is not enough time”, but in light of the level of decision failures and the fact is that later changes always cost orders of magnitude more than good early decisions.

Decisions of the 2nd Kind – Probabilistic

Even if a structured method is used, much system design is based on deterministic estimates and analysis - single value analysis. Concern about uncertainty is accounted for by using a sensitivity analysis around the chosen configuration and the risk of the system failing is tied to the sensitivity. This philosophy of finding a deterministic solution then accounting for uncertainty is a weak approach. Dr. Genichi Taguchi (Taguchi 1999) developed a two-stage optimization that emphasizes the reduction of the effect of noise (i.e. uncertainty) before bringing a system onto target.

While not following Taguchi’s philosophy to the letter, another result of the GAO study focused on the level of risk assessment including technical risk, programmatic risk, and operational risk. Twelve of the projects conducted “limited or no risk assessment” for each alternative. Of these twelve, 67% had high cost/schedule growth. The other 10 projects were judged to have “Adequate Risk Assessment”. Of these, 70% had low cost/schedule growth. The GAO report concluded from these results that if AoAs do not examine risk, then they are likely to present overly optimistic assessments of the alternatives. Uncertainty, and thus the risk, can be reduced during a project only through the expenditure of resources (e.g. Do more analysis to reduce the uncertainty). The cost is much lower than making changes later.

To address risk in the decision making process, the uncertainty in each evaluation must be addressed. One method is to use Bayesian methods – traditionally used to model uncertain systems, detect spam, and decode ciphers amongst other uses. Bayesian methods give a firm underlying mathematics that supports uncertainty, can manage incomplete information, can combine qualitative assessments with quantitative, can fuse team member evaluations and provide what-to-do-next analysis as part of a clear rationale.

Often, during the evaluation of alternatives there are inconsistent results. Where one evaluator thinks the team is strong another may not see it the same way. Where one evaluation of the response time yields one result, another model or source of information may not agree. Bayesian updating allows for the combination or fusion of inconsistent evaluations and provides measures for team evaluation consensus. If consensus is high then there is strong confidence in the evaluation. If it is low, then perhaps this inconsistency should be resolved. Guidance on whether or not to resolve low consensus is also possible through Bayesian analysis.

Bayesian methods allow the calculation of the Value of Information (VIO). This analysis identifies which cells in the decision matrix should be refined with additional effort. In other words, it identifies which evaluations, if refined, could change the satisfactions values significantly. This analysis helps build the rationale (not just record it) by guiding the evaluation of alternatives, the evaluation of them and the selection of the best one.

Bayesian methods can extend rule-based (Kind 1) systems with Bayes Nets or systematic methods (2^{nd} Kind) with the Robust Decision Making method in *Accord*™. *Accord* is an effort to embody the six steps of 1^{st} Kind systems with the assumption that all information, whether quantitative or qualitative, is uncertain and that evaluations are generated by a network of stakeholders who may not agree, but who all need to be enfranchised. This system moves the systematic methods into a probability space enabling the integration of qualitative and quantitative assessments in a consistent, supportable analytical framework. It has been challenging to get these methods adopted as there is great resistance to structured methods (Kind 1) which require a level of maturity beyond even basic structure.

Decisions of the 3rd Kind - Adaptive

Adaptive decisions, those of the 3^{rd} Kind, rely on a set of interacting computer and human entities, forming an integrated whole that together are able to respond to information as it accumulates and is refined to yield the best possible decisions. Such systems react to changes in real time and learn from past decisions. They are structured, yet support informal interactions; they compute and warn of risks and identify the value of new information. They work in a social stream to collect the best evaluations from all stakeholders in the attempt to find the best alternatives, those that are as insensitive as possible to the uncertainties and as satisfying as possible to all stakeholders. These systems are history based, learning from the successes and failures of past decisions. These systems understand the decision-making styles

(Ullman 2006, 101) of the contributors and grooms information to best communicate with them.

What is most interesting here is that while 1st and 2nd Kind systems have only weak adoption, it is the maturity of very fast, unlimited memory, web-based, social stream computer systems that may facilitate their integration in the day-to-day systems development work stream yielding 3rd Kind systems. In other words, adoption may skip the adoption of 1st and 2nd Kind systems and see their functionality integrated into Product Lifecycle Management (PLM), Business Intelligence, Enterprise Management and other higher level, integrated systems. Details for a Type 3 PLM system are described in a recent paper sponsored by Siemens (Ullman 2012).

Final thoughts

What you can take away from this essay to help develop better systems in a more timely manner can be summarized in three thoughts:

1) Adopt decision thinking: As you develop a system and all its sub parts, be aware of the decisions being made and the structure that underlies them as itemized in the 1st Kind.
2) Work from uncertainty – As you make decisions be aware of the uncertainty of every piece of information on which the decision is based as discussed in 2nd Kind.
3) Look for ways that adaptive human-computers can help you make decisions and push managers and software vendors toward such systems. This does not mean, better analysis, better CAD or better plotting; rather it is support for the very structure of the decision making process and the effect of uncertainties on it.

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