Teaching about the Future
Forecasting
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Purpose

The desire to know the future is as ancient as humans themselves. It is our unique ability to conceive of states that are not present to us at the moment that got people thinking about the future (and about the past). And just as history was based on myth and legend before the first historians (Herodotus and Thucydides) decided to write down exactly what happened, so trying to know the future (forecasting) was based on set of beliefs and superstitions that were of little use, except perhaps to make people feel better. Some wonder whether we are much better today with our fast computers and Internet resources! At any rate, while knowing exactly what will happen in the future is impossible, futures studies is nevertheless taking its place alongside other skills, like management, marketing, and policy making. We do all these imperfectly, but better than we used to. On the other hand, we will never reach the accuracy of prediction that the physical sciences have. Some knowledge of the future, imperfect though it be, is better than no knowledge at all.

But is knowing what will happen in the future the only benefit of futures studies? If we cannot know the future exactly, is it worth looking at all? Yes, there are other benefits of looking into the future even if we cannot predict it accurately. One of the other benefits is to appreciate the dynamics of change--how the future is unfolding. Even though predictions are inaccurate, we can still get a sense of how things change.

In fact, that was the rationale for the very first scenario work done in the Pentagon and at the RAND Corporation in the 1950s. Military planners were faced with a new type of warfare with the appearance of intercontinental ballistic missiles tipped with nuclear warheads. Conventional wars take a while to get going. Moving men and materiel into position takes time, and that time is used to plan the campaign. Not so with nuclear weapons. A nuclear war could be over in hours rather than months or years. Planning time was over once the missiles appeared on the radar screen. But strategists did not just wait for that to happen. They conducted war games with one side playing the U.S. and the other side the Soviet Union. The record of those simulations are probably still classified, but one can imagine that a lot of it was, “We will do this, and then they will do that, and then we will do the other thing,” and so on. Each of these simulations was a mini-scenario about how a nuclear war might progress. In the end, the teams were exploring the space of possible moves, and counter-moves, and counter-counter-moves. In essence, they were getting a feel for how things might happen even though they could not tell which scenario was going to occur.

And simulating the future is not confined to the military.. Shuttle astronauts and emergency preparedness agencies run through dozens of risk scenarios in order to be prepared for the one that does occur. Sports teams will have their red team run the other teams plays just to get a feel of the game. And even if none of the scenarios actually occurs as simulated, at least those in charge have a better idea of how the things work and the tools they have to influence the outcome. In the same way, scenario forecasts are simulations of what might happen--not to predict what will happen or even to hedge our bets by making multiple predictions, but rather simply to understand the dynamics of change.

A third reason for looking into the future is actually to know ourselves better. Forecasts, like all inferences, are based on two types of knowledge – information (data) and assumptions (beliefs). We use data in constructing forecasts, but the assumptions are more important and more suspect than the data. How do things work? What leads to what? What's possible or impossible? No one knows the answers to those questions, particularly in human systems, so we make assumptions. Ironically, even though assumptions are the key to making good forecasts, we are often not aware of the assumptions we are using. So discovering and challenging assumptions is essential for good forecasting. Rather than simply waiting to see if the forecast comes true or not, which is what many people do, we imagine how it might turn out differently. Each of those scenarios rests on the same data, but they use different assumptions. Thus we can proceed with a little more assurance that we may not be blind sided by an assumption that we did not even know we had.

Approach

Regrettably forecasting is not taught in school despite the fact we think about the future all the time and a lot is riding on how well we do. Will the light change before I get there? What's for dinner? How long before it rains again? And over longer timeframes – When's the best time to buy a car? What should I major in? Where should I put my savings? So it's unfortunate that we do not teach forecasting in school because could sure use that skill in life!

Nevertheless, we do get ideas about the future in school even though it is not regularly taught. In science class, for instance, we learn how to predict natural phenomena, like the period of a pendulum, the force of a lever, the time it takes an ice cube to melt. We know that scientists are making predictions all the time—the phases of the Moon, the weather for the coming week, the heat of a reaction in a chemical plant, the warming of the planet. And most of those are quite accurate and useful for managing our world. So we learn from science that forecasting is prediction.

We move from the physical world, the world of things, to the social world, the world of people, in history class. We learn history as a series of events—wars, elections, revolutions, natural disasters, etc. Each of those events did happen, but they did not *have to* happen. They were not determined by known laws the way the phases of the Moon are. They are contingent; they depend on the circumstances and the context.

Psychology, sociology, anthropology and political science take different look at the social world, a presumably more scientific one. Can we make predictions in society the way we can in the physics lab? Unfortunately, not. Economists are pretty good at telling us what the economic growth will be over the next year--that is, of course, until they are not. For instance, few predicted the housing collapse and the banking crisis of 2008. That type of massive error rarely occurs in physical science, but it happens in social science all the time. In fact, social scientists often do not make just one prediction; they much make multiple predictions based on different theories. There are patterns in human behavior that we know, but predicting human behavior accurately is not one of them.

So now we are confused. Is the future predictable or not? And the answer is—sometimes it is, sometimes not, but we can't tell when it is and when it is not until it occurs, which of course is too late to do anything about it! And just to make matters worse, we have a third set of people telling us how to predict the future. Alan Kay famously said, "The best way to predict the future is to invent it." A nice catchy phrase, if it were only true. But parents, teachers, ministers and every motivational speaker on the planet all tell us that our future is up to us. You can be anything you want to be; you can reach any goal you choose. Well, we know that is not entirely true, but it does raise the question about how much influence we do have over the future. I can have any flavor of ice cream I want, but can I have any career? Probably not.

So now we have three ways of handling the future. We learned each one from reputable sources, but they appear to contradict each other. Science says that we can predict the future, but historians and social scientists say no, the future is contingent. Alan Kay and many others say we can create the future, but that doesn't always seem to work. So which is it – the predictable future, the contingent future, or the chosen future? In the end, as we saw in the very first chapter, it is all wrapped into a model of change. The future is predictable to some extent because the expected, surprise-free future is more likely than any other single future. But the expected future will probably not happen exactly as we expect it; something else is bound to happen instead (alternative futures). And we can influence the future to some extent (outbound change), but the world will influence the future as well (inbound change).

So forecasting is the process of discovering and describing plausible futures—those that are more likely than any other (the expected future) and some of the others that might happen instead (the alternative futures). Planning is taking that information and combining it with our values, aspirations, preferences, needs and desires to design a way to influence the future toward our vision and goals, literally to bend the trajectory of the future to a more preferable future and away from a less preferable one. This chapter is about forecasting; the next will be about planning.

Support

Forecasts are statements about the future. We cannot observe the future directly so any statement we make about the future is an inference. We make inferences all the time in science, in history and in everyday life. No one has directly measured the distance from the Earth to the Sun, but we know that it is 93 million miles because we infer it from other information. No one alive today was in the American Revolution, but we know (infer) that Washington crossed the Delaware and surprised the Hessians at Trenton in 1776. We know (infer) that the train will leave the station at 11:00 am although we are not there yet. Each of these cases involves knowing something that we cannot directly observe. They are all inferences.

Forecasts are inferences, too, just like the knowledge we have about the world that we cannot directly observe. Secondly, any inference can be wrong. (Direct observations can be wrong, too, but much less often.) So we say we *know* things that we cannot directly observe, but that knowledge is always uncertain. Rene Descartes touched off a philosophical and scientific revolution when he realized that he could doubt everything except his own existence, that everything he *knew* about the world was uncertain to some degree. So forecasts could be wrong just like any other inferences.

Thirdly we cannot prove that an inference is correct the way we can prove a mathematical theorem. Rather we provide support for an inference using two types of knowledge – evidence (data) and assumptions (beliefs). Evidence consists of facts that we and others accept as true. They can be wrong, too, but only rarely so. The evidence we use to support inferences is usually pretty solid.

No, the weak links in supporting inferences are the assumptions required to use the evidence to support the inference. A scientist's assumption could be that an anomalous reading from a measuring instrument is due the instrument not working properly. That assumption always occurs to airline pilots when they get a warning signal Is it a real warning or a faulty sensor?. That assumption actually played a role in the discovery of the destruction of the ozone layer in 1989. It turned out that instruments aboard satellites were already measuring less ozone for most of the 1980s. Scientists assumed, however, that the instruments on the satellite were decaying and sending back erroneous readings. It was not until they received corroboration that they had to revise their assumption, make a different inference and begin to address the problem.

Historians and paleontologists make assumptions as well. Dating fossils assumes that Carbon 14 decays at a set rate. Using photographs assumes that the photograph has not been altered. Eye witness accounts of historical events assume that the observer was there and able to see the event as it happened. They also assume that the account was not unduly biased by the observer's values or prejudices. All of these assumptions are pretty strong and so are the inferences they support.

Forecasters use evidence and make assumptions just like scientists and historians do. The evidence includes quantitative trends over time (trend extrapolation), goals and plans of individuals and organizations (stakeholder analysis), past situations that are similar to the present one (historical analogy). The evidence is solid—those trends have been going on, individuals and organizations did announce those plans, and the present is like an historical situation to some extent. But the assumptions that forecasters make are considerably different from those that scientists make. The speed of light and the decay of Carbon 14 are well established, but will a trend continue? Will that individual or organization be able to execute their plan and achieve their goal? They probably will, but there are many ways in which they could fail. Everyone makes inferences, and all inferences use assumptions. Therefore all inferences are uncertain to some extent. The degree of uncertainty, however, varies among disciplines. Assumptions in the physical sciences are usually very good, but in the social sciences, such as forecasting, the assumptions are weaker. As a result, the inferences are more uncertain. Forecasting is a useful, even necessary activity, but we must deal with the inherent uncertainties involved.

Uncertainty

All inferences are uncertain to some degree, but the uncertainties involved in forecasting are much larger than in most other disciplines. Therefore, we must be more careful in recognizing the sources of uncertainty and in managing them. It does no good to simply assume the uncertainties away, the way many forecasters do. We must identify and deal with them.

Uncertainties appear in two forms—some can be reduced by time and effort and some cannot. We can always gather more and better information and test our theories and assumptions more thoroughly. So far so good, but the irreducible forms of uncertainty are the bigger problem. There are four major types of uncertainty that no amount of time or effort will make go away or even reduce.

Chaos

The first form of irreducible uncertainty is chaos, states in a system that break the rules of predictability. Before 1960, there were two types of systems: deterministic systems were governed by mathematical functions and stochastic or random systems were governed by the laws of chance. Deterministic systems were predictable. Enter a future value for time into the mathematical function, and the predicted quantity would result. The solar system was the ideal deterministic system in which eclipses of the moon could be forecast millennia in advance. Stochastic systems were unpredictable since every trial was independent of the previous trials--flipping coins or rolling dice, for instance. The distribution of many trials would form a pattern, but that pattern could not be used to predict the outcome of any one trial, no matter how much data were collected.

Systems in chaotic states emerged in the 1960s to form a third class, systems that were deterministic yet unpredictable. Each new value of a system in a chaotic state is a mathematical function of the previous system. In general mathematical terms, $f(x_{t+1}) = f(x_t)$ or any value x at time t+1 is a function of (or calculated from) the value of x at time t. These systems have a special type of mathematical form called recursion, the next value in the series is based on one or more of the previous values. If one chooses the parameters of the equations correctly, the systems exhibit chaos or sensitivity to initial conditions. If two series start out with the same initial values, they will follow the same path; that's determinism. But if they start out with any difference, even one that is infinitesimal, their paths will diverge before too long. In essence, the feedback of recursion, multiplied over even a few trials, becomes so great that the series quickly diverges. The series is unpredictable because one cannot measure the initial conditions of real any system to an indefinite accuracy. There will also be some rounding, and any rounding is enough to create a different future for that system in the medium-term.

Systems in chaotic states break the relationship between determinism and predictability. They are deterministic, but they are not predictable. Examples of systems in chaotic states in the real world are the weather, heart rhythms, brain waves, probably the stock market, unstable political movements and many more. No matter how much information one collects about these systems, they are inherently unpredictable. We used to think it was our method that was at fault, that if we just studied harder or learned more, we would be able to predict these systems. That was the hope of the Enlightenment based on Galileo's, Kepler's and Newton's extraordinary theories that explained and predicted the motion of the planets so well. But we have been disappointed, and now we know why.

Criticality

Another state of unpredictability in deterministic systems is the super-critical state. Many systems have a virtual maximum for the value of a variable in the system that is called its critical value. There is a critical value for humidity in air at a given temperature above which the water precipitates out and it rains. There is a critical angle for sand of a given viscosity in a pile above which it collapses. Avalanches, earthquakes, breaking waves are all examples of systems that have exceeded their critical values.

It is possible, however, to go beyond the critical value, to go super-critical, just a little and for a short time before the system abruptly returns to a sub-critical value. So one can create a super-critical angle in a sand pile by adding the sand one grain at a time. At some point, that next grain will start a chain reaction, a mini-avalanche, and the pile collapses. One cannot tell, however, which grain will start the avalanche. The only thing we can say is that the higher the value above the critical value, the more likely any disturbance (the next grain) will "collapse" the system back to a sub-critical state. And as with the equations of chaos, we know the critical value for physical systems, like gases, liquids and sand piles, but we do not know the critical value for social systems. How fast can a system grow? How much stress can it stand? How much beyond historical values can it go before it "snaps"?

The current term for social systems in a super-critical state is a bubble, what the world experienced in the housing-debt-banking crisis of 2008. How big can a bubble get before it bursts? We do not know. We know that all bubbles burst eventually. However, whether a change is a bubble or not is open to some dispute. We only know a bubble for sure after it has burst, not before. During a rapid change in a social system, something which might be a bubble, some argue that the system is not super-critical at all and that it will not burst. Rather they argue that the system is going through an S-curve change from a old lower value to a relatively permanent higher value because of some change in the system itself. S-curve changes do happen. The average speed and distance of human travel has fundamentally increased with the appearance of the automobile and the airplane. Those were not bubbles; they did not burst, at least not yet. But the economic growth from 2005 to 2008 was a bubble, as was the tech bubble in the 1990s and the stock market crash in 1929. There are the whose who claim to be able to tell the difference, but no such scheme has achieved widespread support.

So as before, we are left with uncertainty. We cannot tell when a rapid change is a bubble that will burst at some point in the future versus when it is a fundamental change that is sustainable in the long run. We know the answer after the bubble bursts, but not before. And even if we know that a change is a bubble, we cannot tell, even in physical systems, when or how the bubble will burst.

Complexity

A third source of uncertainty is a completely different conception of the underlying mechanism of how a system operates. Systems engineering, the reigning paradigm of systems analysis, views a system as a set of variables. In a physical system like a gas, the variables are temperature, pressure and volume. Important variables in economic systems are interest rate, growth rate, and unemployment rate. In social systems, they might be population size, ethnicity and family structure. Systems analysis discovers the relationships among these variables and expresses them as charts or equations or even computer simulations. This approach to system structure was developed in the 1940s and has been the basis for systems engineering which in turn led to most of today's complex systems, such as the telephone system, airplanes and spacecraft, power plants, even the Internet.

Another way of understanding systems emerged in the 1980s, mostly at the Sante Fe Institute. There scientists revived an old idea of cellular automata, basically small theoretical machines that act using a given set of rules in a specific environment. The result of many automata interacting in the same environment can be a complex adaptive system (CAS). One of the first and perhaps most famous example of CAS is the Game of Life created by John Conway in the 1960s. Conway created a grid of squares where each square was "on" or "off" depending on the state of the eight squares in its neighbors If three of the neighboring squares were on, it turned on; if two or three of those squares were on, then it stayed on; otherwise it was off. Simple structure; simple rules.

But what emerged from this arrangement were shapes and behaviors that no one could have predicted. These shapes and behaviors are the emergent properties of the system because they emerge from the underlying structure. They are in fact "caused" by that structure, but the causal link is so unusual that no one can predict what the emergent properties will be from any given underlying structure. In fact, the emergent properties are often quite orderly and even beautiful, but they are completely unpredictable.

Many systems in the world today act like complex adaptive systems--independent agents acting according to a set of rules. Isn't a market that structure--buyers and sellers acting to maximize their advantage within a set of rules? Isn't the election system in a democracy or the law making system in a legislature that structure? What about an ecology--many individuals of many species interacting to form a stable environment? In fact, what is not in the form of a complex adaptive system, except non-living things and artificial things like machines and organizations?

We thought that our machines were mimicking nature, and they were, but only one part--the mechanical part which follows the predictable laws of mechanics. The living part of nature, including human societies, follows the rules of complex adaptive systems and displays properties and structures that emerge unpredictably from their underlying structures. Such systems are, or can be, creative--producing novel arrangements. So multi-cell organisms grew from single-cell ones; sentient organisms grew from non-sentient ones; intelligent ones grew from non-intelligent ones, and so on. Life is creative, and human life the most creative of all. Can anyone predict what the next creative leap will be, the next big thing? Of course, not; no matter how much information and research one applies, creativity will never be predicted. So if the future is creative, if it involves new elements never before seen, do we give up? No, but more on that later.

CAS are not always throwing off new emergent properties. Most markets are quite regular most of the time—hence the economic laws of supply and demand. Some markets, however, are unstable and emerging markets. Take for example the wireless markets of 1998-2002. whose rules and forms were being created and re-created everyday by the action of major stakeholders (engineers, telephone companies, customers, regulators, etc.). No one can predict what that market will look like in the future because the emergence is not finished. It may be 10 years before the main outlines of that market are known and become stable.

Most markets are not in that turbulent state of initial emergence. Nevertheless, there is still an uncertainty in all CAS. Take the stock market, a CAS studied perhaps more than any other. There is some understanding (leading indicators, repetitive cycles, technical analysis), but there is also vast amounts of uncertainty. Since all the effort that has gone into predicting the stock market has not paid off, we might then conclude that any CAS, including most aspects of society, are inherently unpredictable.

Choice

The fourth and last category of uncertainty is the most obvious yet most often overlooked source, human beings themselves. Early in the 20th century, behavioral psychologists hoped that they could predict human behavior by knowing the conditions under which humans acted. They made a lot of progress because humans are conditioned by their environment. But they failed in the end because humans can go against or transcend that conditioning, and scientists cannot tell when that will happen and when it won't. Philosophers call it free will, the ability of humans to make choices unconstrained by circumstances. If the ability to choose is actually free, then it is also unpredictable. Most people believe that humans are at least partially free. That part then is unpredictable when considering the future of human affairs.

Methods

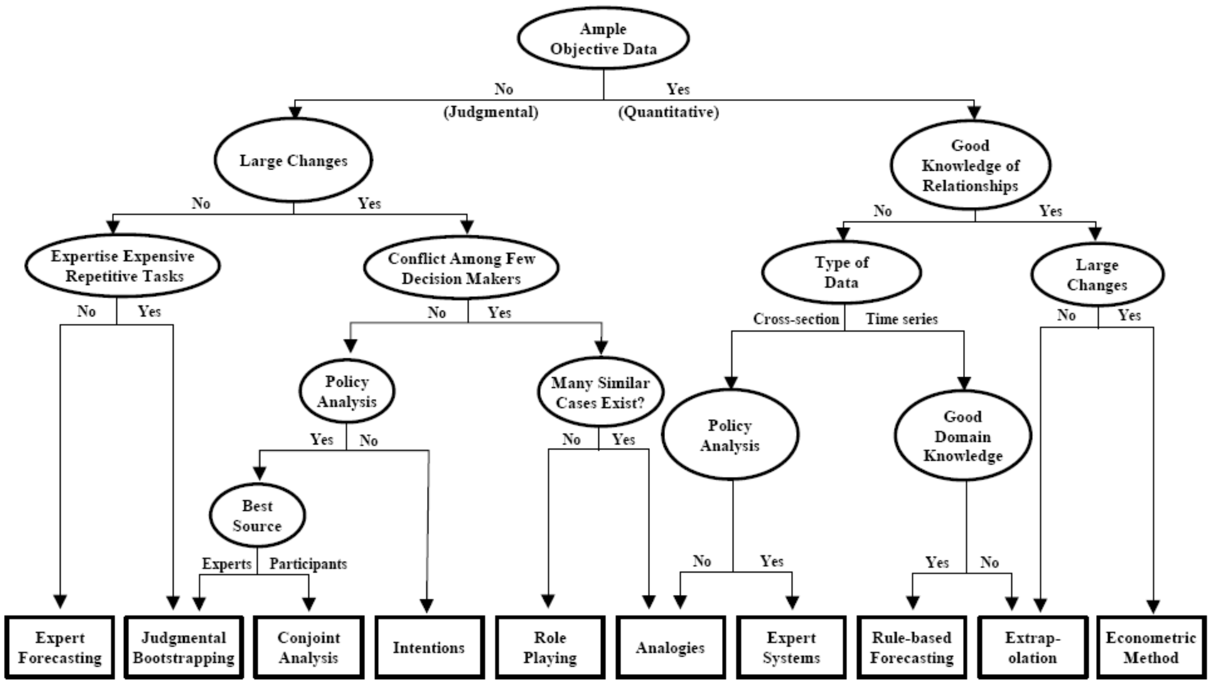
So to review the bidding before we leap into the methods used in forecasting –

- Forecasts are statements about the future.
- We all make forecasts all the time although few of us were taught to do so in school.
- Since the future is unobservable, forecasts are inferences that are supported by evidence and assumptions, just like inferences in other disciplines.
- But the assumptions used in forecasting are weaker than those used in other disciplines, introducing more uncertainty into forecasting inferences.
- What is more, certain system states (chaotic, critical, and complex) are inherently unpredictable, not to mention human choice based on free will.
- Therefore, forecasting techniques must identify and manage the considerable uncertainties involved.

The conclusion then is that forecasters of human systems cannot simply borrow techniques from the physical sciences. Human systems are a different class of phenomena that requires a different approach to forecasting.

The most comprehensive review of forecasting techniques is *The Principles of Forecasting* (Armstrong, 2001). Armstrong included this map of forecasting techniques in that publication.

Selection Tree for Forecasting Methods



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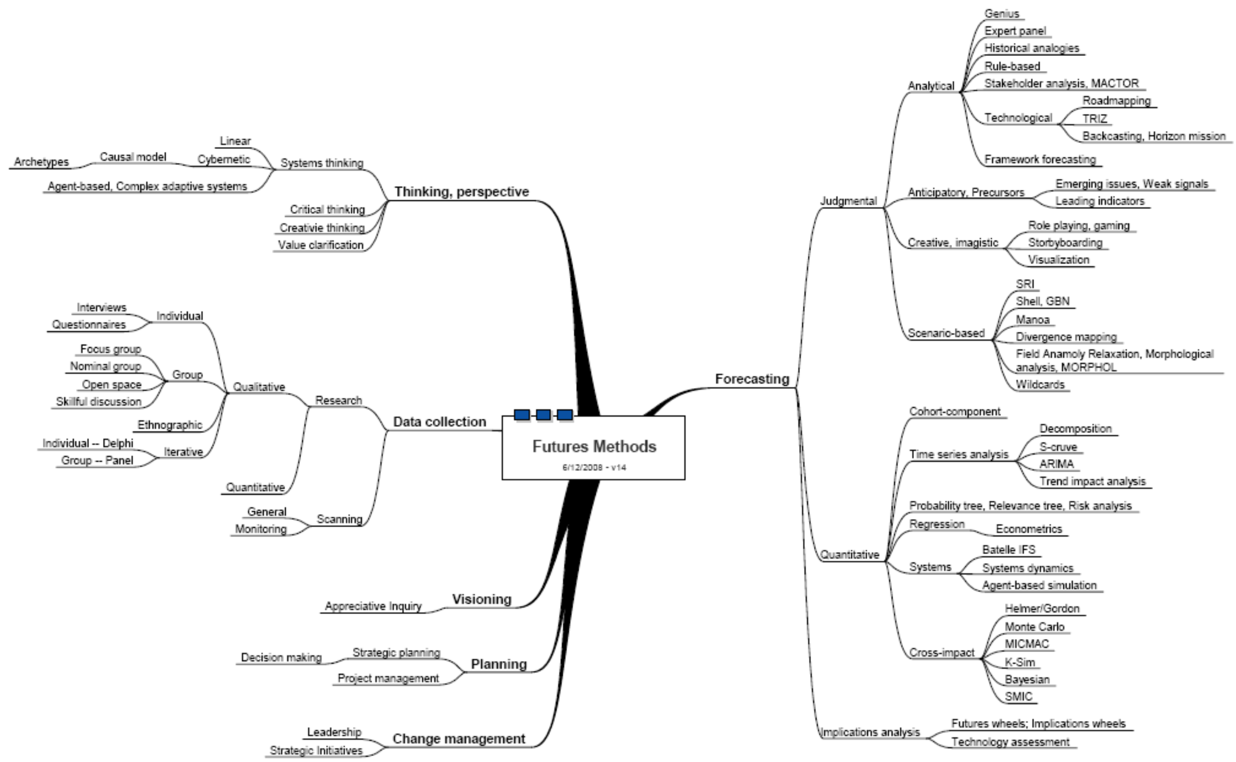
Whether one agrees with the decision tree or not, the tree does include many of the common forecasting techniques in use today. Those most commonly used by futurists for long-term, forecasts include –

- Expert (or genius) forecasting
- Judgmental bootstrapping (interviews and surveys, including the Delphi technique)
- Intentions (stakeholder analysis)
- Role playing (war gaming, simulation)
- Analogies

Futurists also use a broader set of systems tools, than just econometrics, to map the structure of the system as described in Chapter XX.

It is immediately evident that futurists tend to use qualitative techniques rather quantitative because of the breadth and time horizon of their forecasts. Quantitative techniques are suitable for relatively short time horizons and relatively narrow domains. But the synthetic power of human judgment and expertise is more appropriate when forecasting over longer time horizons and broader domains.. Quantitative data does exist for many variables, but extrapolating that data over 10-20 years is quite risky. Futurists also tend to focus on potential future discontinuities and transformations for which quantitative analysis is not appropriate at all.

Another map of futures methods, developed by Bishop and Pero Micic, is contained in this figure.



6/12/2008 Developed by Peter Bishop (UH-Clear Lake) and Pero Micic (FutureManagementGroup)

The right side of this figure (the forecasting branch) begins with the judgmental-quantitative branches that Armstrong uses. The forecasting branch also includes a small branch devoted to implications analysis.

In addition, four fundamental thinking styles used in futures work are listed at the top left. The first three are directly related to forecasting – understanding the structure of the system or domain to be forecast (systems thinking), evaluating the support for inferences about the future of that system or domain (critical thinking), and imagining new events or conditions that could occur in the future (creative thinking). One can use value clarification in forecasting when evaluating the attractiveness of various scenarios, but value clarification relates more directly to selecting preferred futures, one of the first steps of strategic planning.

A paper published by Bishop, Hines and Collins in 2007 surveyed the techniques used in developing scenarios. They classified the 22 techniques found into eight major categories –

- **Judgment** – like Armstrong, human judgment and estimation, including the Delphi method
- **Baseline** – quantitative techniques involving one variable, including trend extrapolation and time series decomposition
- **Fixed scenario** –fixed scenario types, such as best-case, worst-case, or wildcards

- **Event sequences –** branching structures of future events and conditions, including probability and relevance trees
- **Backcasting –** positing a distant, plausible future and working backward on how that future could occur, including Horizon Mission Methodology and the Impact of Future Technologies
- **Dimensions of uncertainty –** morphological analysis, including the Shell/GBN four-quadrant matrix
- **Cross-impact analysis –**the impact of trends and potential events on one another, including Monte Carlo techniques
- **Systems modeling –** systems dynamics and other mathematical ways of simulating the effects of multiple variables, including cohort-component and econometrics

The study was intended to focus on techniques that futurists use to construct alternative scenarios. The authors realized early on, however, that any forecasting technique could be used to construct an alternative scenario, even the most quantitative technique, because all forecasts rest on assumptions and varying the assumptions automatically creates alternative scenarios. By the same token, any technique that futurists use to create alternative scenarios can also be used to forecast the expected future by selecting the most plausible assumptions. So there really is no difference between the techniques used in predictive versus alternative futures forecasting since all rest on assumptions, some of which are more plausible that lead in the expected scenario while the others lead to the alternative scenarios. All forecasting uses the same techniques whether the result is the expected future or some of its alternatives.

References

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Bishop, P., A. Hines, & T. Collins. 2007. "The Current State of Scenario Development: An Overview of Techniques." *Foresight*, VOL. 9 NO. 1, pp. 5-25,