# NETWORKED ANTICIPATORY SYSTEMS

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## Extended abstract

Anticipatory networks (ANs) are a relatively new tool in decision theory, strongly related to other approaches to researching the future [3,4]. Based on the fundamental notion of *anticipatory feedback*, ANs are capable of linking information about the future gathered with forecasting and foresight to present-day decisions. Thus ANs allow decision analysts to formalise the preferences concerning the decisions to be made by other decision makers in the future. The ANs generalise earlier anticipatory models of decision impact in multicriteria problem solving [2] and constitute an alternative decision model to utility or value function estimations and to diverse heuristics. Furthermore, ANs provide constructive algorithms to fuse multi-stage multicriteria forward planning and multicriteria backcasting and to computing nondominated strategic plans that comply with a given anticipatory preference structure [3,4].

This paper presents recent research on Anticipatory Networks, extends earlier results on the *superanticipatory systems* theory [5], interactions between artificial anticipatory decision makers [6,9], and various applications of ANs as impact modelling tools in multicriteria strategic planning [3,4,8] and foresight [2,3]. We will show how to apply preference structures embedded in ANs to derive anticipatory decision-making principles and how to construct and filter scenarios corresponding to rational and sustainable future visions.

An AN is a connected directed multigraph *G* with nodes corresponding to anticipatory systems and edges modelling the relations between them. A starting node in an anticipatory network models an anticipatory system that solves a present-time multicriteria decision problem. Obviously, starting nodes have no predecessors. The other nodes model systems making their decisions in the future. Following Rosen [1], each of the them builds a world model and extrapolates it into the future until a prescribed forecast horizon. The world models contain the models of themselves and of other anticipatory decision makers in the same network. Some of such future nodes may model further stages of evolution of present-time decision makers. Networks that contain such nodes are especially well-suited to model sustainability problems.

The multigraph $G$ contains at least two different types of edges: causal and anticipatory. The edges of the first kind model the causal dependence of decision problems solved by some future anticipatory systems on the solutions of certain earlier problems. There may be several kinds of causal relations represented in one network. By assumption, the causal subgraph $G_c$ of $G$ does not have any loops. Subsequent decisions made along a chain of causal dependences in an AN model the consequences of decisions made at earlier nodes of this chain [2]. We assume that decision makers responsible for solving problems defined at network nodes $O_n$ may take into account anticipated outcomes of some future decision problems linked by a causal relation with $O_n$. Specifically, when solving his/her problem, the decision maker modelled by $O_n$ tries to manipulate the predicted consequences of the decision just being made so that a certain future decision maker $O_m$ dependent on $O_n$ is forced to select their decisions from a given subset $V_{m,n}$., or at least the probability of choosing the $O_m$'s decision from $V_{m,n}$ is maximal. This concept supplements causal network of anticipatory decision-making systems by the relation of *anticipatory feedback* [3].

The basic principle of processing information contained in ANs can now be formulated as follows: *the decision in an AN is made after an analysis of causal relations that link the outcomes of the current problem with their future consequences* [2], *taking into account all anticipatory feedbacks* [3]. Beyond the above anticipatory decision rule, all decision makers $O_n$ can explore an additional preference structure $P_n$. By definition, the best-compromise scenario describes the most desired future and starts from the present-day best-compromise decision. The above relations allow the decision makers to confine the sets of admissible nondominated decisions at the starting node(s) of anticipation. For example, in foresight, AN-based assessment processes allows $O_n$ to select a subset of normative scenarios, then run an AN-based backcasting.

In the anticipatory network theory presented in this paper, the decision makers can impose causal dependences on constraints and preferences in future decision problems, depending on the outcomes of the decision just made. Since only some decisions may lead to desired consequences, this allows the decision makers to construct an additional preference structure that supplements the one existing at a initial node. Finally, the analysis of an AN consists in appropriate simultaneous handling of both types of relations, causal and anticipatory. Usually, this analysis is uses forecasts and exploratory scenarios regarding the future decision model parameters. A standard approach consists in using quantitative outcomes of expert Delphi surveys [7], other foresight exercises, or time-series–based extrapolation forecasts.

All nodes in an AN that have a successor and are target nodes of an essential anticipatory feedback are termed *active*. For a given *G* there exists its unique subnetwork *G'* that consists of active nodes only and is maximal. It may be proven that all decision making problems formulated in G and referring to the decisions made at active nodes can be solved equivalently using the information contained in *G'*. The above-mentioned relations form a complex information model that extends the Rosen's anticipatory systems theory [1]. Specifically, it can be proven that - under some additional assumptions - active nodes in an AN are *superanticipatory systems* according to the definition given in [4,5], i.e. they are capable of modelling itself and other anticipatory or superanticipatory systems.

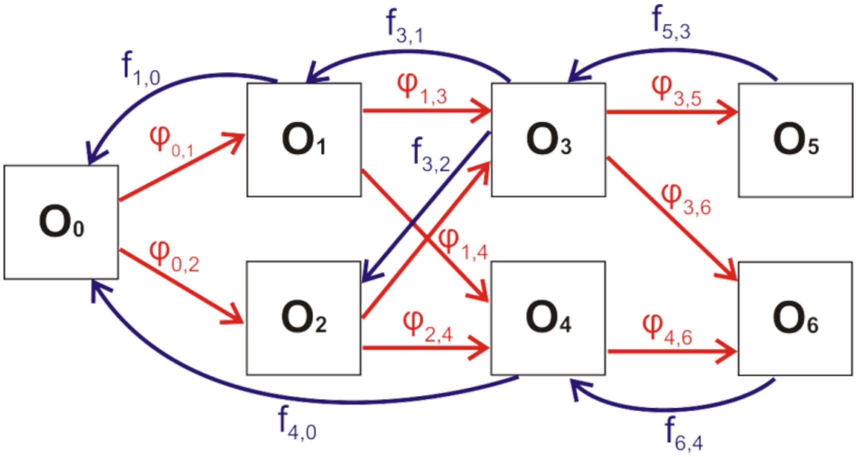

Fig. 1. *An example of an anticipatory network of decision units: the nodes $O_i$, i=0,…,6, denote multicriteria decision units, red arcs denote causal influence relations and temporal order between the decision units, blue arcs denote anticipatory information feedback that indicates which future decisions are relevant to decision makers preceding the corresponding decision units in the temporal order* (*source:* [8])

While the foresight-oriented applications of ANs may be regarded as characteristic for this class of decision modelling tools, we should also mention a other fruitful applications of the AN-based decision model, such as coordinating swarms of autonomous vehicles with *timed anticipatory networks* [9]. There exist many theoretical and application-oriented problems related to ANs that require further research. Some of them will be presented to the audience of this Conference.

**Keywords:** Anticipatory networks, Superanticipatory systems, Strategic planning, Multicriteria analysis, AI future.

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