A quickening, if still somewhat quiet, shift in the balance of practical power from men to machines is now well underway. In more and more application areas, and more and more completely, decision authority is being removed from human functionaries and reassigned to computer-centered constructs. Such constructs will here be denoted as *Directive Decision Devices*. They are distinguished from other types of technical artifices not just by their ability to act as entirely autonomous decision agents, but also because any humans that happen to come into their company are also likely come under their command. There are opportunities for variability among directive decision devices, both as to mission (of which there are at least four distinct categories) and instrumental content. It seems, however, that most directive decision devices — existing and prospective alike — will tend to cluster around one of eight configurational ideal-types. When these prototypical directive decision devices are arrayed on a continuum of capabilities, those sitting towards the low end of the continuum will be comprehensible as *automata*-type appliances, while those positioned towards the more capable extreme will be strongly reminiscent of *cybernetic* process management systems.
I. FOREWARD

The term *Directive Decision Devices* is here used to denote a class of computer-centered constructs intended not to support human decision-makers, but to displace them. In this sense, directive decision devices serve as repositories for decision responsibilities that might otherwise be invested in human functionaries. They serve also to sustain the shift in reliance from men to machines that's been underway since the advent of automation. Actually, because they are decision agents and not just agents of production, what might better be said is that the emergence of directive decision devices has moved the man-machine confrontation onto another dimension altogether. On this new dimension, what's afoot is nothing less than a shift in the balance of practical power — a redistribution of decision authority.

How this might go requires getting some fix on the feasible technical reach of directive decision devices by attempting an answer to this question: As things now stand, what is the most in the way of capabilities —analytical capabilities, most critically— that can be incorporated in a computer construct? The domain of practical authority for directive decision devices would then extend to include those decision situations whose requirements —analytical and otherwise— do not exceed these capabilities. As will be argued here, this domain is not so extensive as the more ardent AI enthusiasts might wish. Like their over-promoted predecessors, *General Problem-Solver* and Expert Systems, contemporary claims about computer programs endowed with higher forms of human intelligence pretty much always turn out to be more precatory than probative. But neither is the domain of directive decision devices as circumscribed as others would have it, particularly those espousing the amiable assumption that machine intelligence can never amount to anything more than mastery over menial matters.

It's true, certainly, that most of the humans that have heretofore been displaced by directive decision devices will have been charged with making decisions that maybe were not all that analytically demanding. But this is maybe less a reflection of strictures on the sorts of challenges that directive decision devices can be expected to handle than of the frequency with which people are employed in positions that impose only relatively menial mental challenges. But a credible case can (and later will) be made that neither higher-ranking managerial functionaries, nor even some professionals, can expect to remain forever beyond the purview of directive decision devices.

For those at whom they are targeted, the most benign consequence of directive decision devices will be a curtailment of certain prerogatives they once enjoyed. In their more aggressive orientations, directive decision devices can dispossess humans of much-valued and perhaps increasingly irreplaceable employments. In the end, though, things turn out for directive decision devices pretty much like they have for most other technical artifices: Some are threatened that others may benefit.

II. SOME SUGGESTED CLASS CHARACTERISTICS

Directive decision devices are first to be distinguished from their more familiar predecessors, *Decision Support System*. The typical DSS will have been authored at the instigation of its user; its mission will then be merely advisory, and its employment volitional. Directive decision devices, in contrast, are commissioned by organizational superiors and subsequently imposed (perhaps surreptitiously) on subordinates. As such, their orientation is neither advisory nor passive, but active and peremptory. Nor, of course, is their employment anything other than mandatory. So, in addition to enabling transfers of decision responsibilities from men to machines, directive decision devices can also enable greater concentration of power in the hands of those sitting towards the apex of any managerial hierarchy. To the extent that they serve to lengthen the effective executive reach of those commissioning them, directive decision devices may be said to put automation in service to centralization. Directive decision devices thus have the distinction of being perhaps the only technical artifices that can legitimately claim to be agents of both automation and autocracy.

Directive decision devices are also distinct from the sorts of computer-based constructs employed in the context of man-machine systems. This includes what are popularly (if not always properly) referred to as *Intelligent Agents*. These are typically intended to perform only clerical-type operations (database searches, situational alerting) that, for the most part, depend less on active intelligence than apparent pattern-recognition [1, 2]. Theirs is thus primarily a passive, informative role; their contribution in collaborative contexts is the provision of decision predicates, not decision-making.
The introduction of a directive decision device into any man-machine arrangement would, in signal contrast, occasion nothing less than an outright reversal of the locus of authority. Rather than having the computer standing in passive subordination to the man, the man would now stand in service to the computer. However, in their more interesting incarnations, directive decision devices will not be deployed in company with humans anyway, but will be designed to act as entirely autonomous agents. Indeed, as will later be argued, the sorts of applications for which directive decision devices are most clearly appropriate are those where the presence of a human is not just unnecessary, but perhaps also undesired! That is, directive decision devices are best deployed in situations where decision-making demands nothing much in the way of creativity, subjective sensibilities, virtuosity or vision. As for the duties that directive decision devices might be assigned, these would appear to fall into four generic tasking categories:

<table>
<thead>
<tr>
<th>TASKING/MISSION CATEGORIES</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>EXECUTORY</td>
<td>Displacement of authority over some type/class of decisions; outright replacement of human functionaries</td>
</tr>
<tr>
<td>COMPENSATORY</td>
<td>Assume authority in areas (or over functions) where human capabilities are expectedly deficient or undeterminable</td>
</tr>
<tr>
<td>INTERDICTIVE</td>
<td>Prevent implementation of improvident or prospectively parlous decisions unless/until sanctioned or corroborated by a higher authority</td>
</tr>
<tr>
<td>COOPTIVE</td>
<td>Seize the initiative in case where a human functionary fails to effect a required action (or reaction) in a timely manner</td>
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As will be discussed in some detail downstream, each of these four categories poses something unique in the way of operating requirements. But there are also some constants. Irrespective of the category in which they fall, and irrespective also of whether they are to act as the superior member of a man-machine amalgam or as autonomous decision agent, there are certain capabilities required of all directive decision devices: (1). All must have some provision for problem-recognition; (2). Thereafter, all need something in the way of embedded instrument(s) to effect the election of decision choices or, more generally, to support response-selection; and (3). Every directive decision device must, finally, have some way of arranging for the implementation (enactment) of the decision choices at which they’ve arrived.

The operational core of directive decision devices is located in the analytical apparatus arrayed against the second of the above requirements. Unlike decision-making or problem-solving exercises undertaken in interactive or collaborative contexts, employing a directive decision device means that the only analytical capabilities that can be brought to a decision situation are entirely a consequence of the instruments with which the device itself has been invested by its designers. This suggests a practical stricture, albeit more arguable than absolute: The only decisions for which computer programs can be held solely responsible will be those involving subjects that are sufficiently well-structured and well-behaved, such that a conventional technical solution is available. The domain over which directive decision devices can reasonably be expected to exercise authority will then be restricted to essentially technically tractable decision situations, i.e., those where an algorithmic or programmatic (scripted) resolution can be realized by taking recourse to one or another of these four families of instrumental facilities:

<table>
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<tr>
<th>TABLE 2: Permissible Instrumental Underpinnings</th>
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<tr>
<td><strong>Deterministic</strong></td>
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<tr>
<td>Categorical</td>
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<tr>
<td>Simple rule-based structures:</td>
</tr>
<tr>
<td>Decision Tables and common Decision Trees</td>
</tr>
<tr>
<td>Computational</td>
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<tr>
<td>Algorithmic formulations centered around ordinary mathematical optimization methods</td>
</tr>
</tbody>
</table>

This would exclude, as candidates for transfer to a directive decision device, any decision situations involving subjects whose characteristics are too complex to be captured by an orthodox quantitative expression or set of such (a solvable system of equations). Excluded also are entire species of decisions for which even objectively-predicated qualitative conclusions are beyond reach, e.g., Speculative, rationalistic (judgment-driven), quasi-axiomatic (precept-driven) and subjective (value-driven, axiological).
III. PROTOTYPICAL DIRECTIVE DECISION DEVICES

In considering the technical reach and limits of directive decision devices, probabilistically-instrumented devices can generally be expected to handle relatively more demanding decision situations than their deterministically-equipped counterparts. But there is also a second dimension on which the capabilities of directive decision devices can be considered. They can also vary in terms of the richness of their corporal content. A their sparsest, directive decision devices may consist merely of a collection of instructions constituting a rudimentary computer program (to be executed in company with whatever data-gathering and decision-implementation apparatus are appropriate to the application at hand). At their more elaborate, they may be comprised of a multiplicity of programs (constituting what’s sometimes referred to as a software suite) conjoined with a perhaps quite extensive assemblage of hardware such as sensor banks, input-output converters, integral actuating mechanisms, monitoring and feedback facilities, etc.

It's thus possible to think of directive decision devices as being arrayed along a continuum of capabilities. What would determine where any particular device would be positioned on this continuum would be a reflection of the resolution power of its analytical instruments and the range of functions it's configured to perform. As with any continuum, of most interest are the sorts of things that would sit towards the two extremes and in the mid-range. Hence the three sets of prototypical (ideal-type) constructs shown in Illustration 1, crafted to suggest, respectively, what minimally, moderately and maximally capable directive decision devices might look like.

Illustration 1: Prototypical Directive Decision Devices

The elementary prototypes are essentially just simple conveyances for the four instrumental categories introduced just above. The two midrange (network-type) entries are node-arc constructs where the nodes contain algorithmic expressions or computational models; this can allow them to undertake supervisory functions in certain application contexts. The final pair of prototypes speaks to the suggestion that, in their most elaborate guises, directive decision devices will have configurational features reminiscent of cybernetic-inspired constructs.

**A. Low-End (Elementary) Devices**

Elementary devices are roughly comprehensible as simple automata-type constructs, with their core instruments analogous to *transducers*. They have only minimal functionality, as their charge does not extend beyond the three essentials: Problem-recognition, response-selection and enactment (a requirement which, in the case of elementary devices, is answered indirectly). They can, moreover, carry out these several functions only in a relatively rudimentary way. They can, first of all, recognize only definite, discrete variations on a single class of problem. Secondly, they are allowed no discretion. Response selection is a purely perfunctory process so that, for any decision situation, there will be only one essentially pre-programmed (design-dictated) decision choice. Any discriminatory capabilities low-end devices have are then entirely inherited, not inherent. Finally, elementary devices have no actuation mechanisms of their own. The physical execution of decision choices must then fall to an external entity of some kind (man or machine). Hence the characteristic configuration for low-end devices shown as Illustration 2, where their endogenous capabilities are confined to those included in the dotted area.
The main point of contrast between elementary devices is thus to be found in their instrumental underpinnings, with probabilistically-instrumented devices (Type-3 categorical or Type-4 computational) being considered potentially more capable than their deterministic (Type-1 and Type-2) counterparts.

1) Simple categorical conveyances

Thus, for example, probabilistic tree-type structures are capable of encoding a higher order of intelligence than decision tables or deterministic decision trees. While decision tables and deterministic decision trees can accommodate only simple associative inferences, probabilistic variants are often asserted as being capable of performing inductive inference operations. Though this assertion will shortly be subjected to certain qualifications, it's clear that operating within the confines of a decision table demands only the lowest form of intelligence, human or otherwise.

Entities having only associative inference capabilities are confined to conclusions grounded in either direct experience, per classical conditioning, like Pavlov's dogs [3, 4], or rote learning (sometimes extended to include transitive learning [5]) via indoctrination for humans or definitive-discrete programming for computers. For the latter, decision tables will be implemented as rule-base structures that include two types of if:then mapping operations:

- **Problem Recognition** (Diagnostic): if \( \{I\}|c \quad then\ M_i \in M \), or \( \{I\}|c \Rightarrow P(M_i \in M) \approx 1 \), where:

  - \( \{I\}|c \) is an input array (a set of observables, symptoms, etc.) for the current case,
  - \( M \) is the problem domain and \( M_i \) a discrete member of \( M \), with the qualifier \( P(M_i) \approx 1 \) requiring effective certainty.

- **Response Selection** (remedial): if \( M_i \quad then\ R_i \), or \( M_i \Rightarrow R_i \), which requires that, for any \( M_i \), there be one and only one singular permissible response option, \( R_i \).

The discretely-recognizable problems included in \( M \) serve to define the rows of a decision table, with the response options (\( R_i \in R \)) arrayed as columns. The result is a neat bipartite structure, \( [M \times R] \) that is absolutely intolerant of ambiguity [6, 7, 8, 9].

This is well enough illustrated in one of the most widely-employed examples of decision-table driven Type-1 devices, computerized automotive diagnostic systems. These are connected to the output bus of an automobile's computer control box. Inputs (qua decision predicates) then take the form of diagnostic codes, each of which (hopefully) identifies a unique problem. The problem domain for the system (\( M \)) consists of all conditions for which there is a discrete code, with each code anchoring a row in a decision-table. As problem-recognition consists entirely of code reading, definitive diagnostic mappings are thus assured, as are forced-certitude response side mappings. For any recognizable diagnostic code, a case would conclude with the system dictating a specific corrective action, which may be enacted in one of two ways, depending on the nature of the correction: The system may direct a mechanic to perform a manual task (e.g., change a bad spark plug) or it may command the automobile's on-board computer to change one or more operating settings (for ignition timing, turbo boost, fuel-air ratio, etc.).

But the response options arrived at by a decision table need not always be conclusive. There are two other possibilities: (1). A solution may require a computational exercise, which might then be dealt
with by passing the problem, via a lateral transfer, to an algorithm-driven device; or (2). A response may execute a link to a secondary (subordinate) decision table, $R_i \rightarrow [M \times R]_2$. If no final solution is found within this secondary table, a tertiary table, $R_{2,3} \rightarrow [M \times R]_3$, might be called, and so on, yielding a multi-stage solution, $M_{1,i} \rightarrow (M_{2,j} \rightarrow \ldots M_{n,k}) \Rightarrow R_{M,n}$. Applications involving multi-stage solutions, however, might better be undertaken by converting from decision tables to deterministic decision trees.

Though deterministic decision trees have no raw capabilities beyond those of decision tables, they are a more convenient way of apprehending applications where problem-recognition requires a convergent (linear or trajectory-type) search process. A decision tree representation would clearly be the better choice for a device designed to trouble-shoot automobile engines for which there are no diagnostic codes. An input to such a system would consist of a perhaps somewhat vague customer complaint(s) — poor acceleration, say. The first task for the device would be to direct a mechanic to take steps that would resolve the paramount causal issue: Is the source of the problem in the ignition, fuel or control (sensor) subsystem? Thereafter, within the offending subsystem, a set of increasingly localized search initiatives would be undertaken until a definite (and actionable) problem-definition has been isolated, and an appropriate correction action commanded. It's important to note that this is not a collaborative exercise; the mechanic acts only at the behest of the device.

It's also important to note that the omission of Expert Systems from this discussion of basic categorical constructs was intentional. The problem is that Expert Systems —true expert system anyway, as distinct from the far more numerous faux expert systems (which are, in reality, merely decision table or decision tree constructs marketed as something more formidable)— are generally unable to operate autonomously. Most true expert systems are, rather, intended to be deployed in a collaborative man-machine context, where it falls to a human user to start things off by introducing a starting hypothesis. Thereafter, they will proceed to test this user-introduced hypothesis against what its rule-structure determines to be the conclusion that would have been reached by the 'expert' the system was designed to emulate, with their performance (especially that of forward-chaining systems) strongly sensitive to the quality of these user-supplied hypotheses. Disparities and/or opportunities for refinement are subsequently addressed interactively, with the expert system acting in an advisory vs. commanding capacity. The upshot is that expert systems can underpin decision support systems, but not directive decision devices.

2) Probabilistic Tree Structures

Assessing the capabilities of probabilistic or stochastic decision tree structures is not so straightforward. As mentioned earlier, it's sometimes claimed that probabilistic tree-type constructs can be used to provide computers with inductive inference capabilities. As it happens, however, most of the computer programs of which this is said actually turn out to be performing statistical inference operations in some partially masked form. Statistical inference instruments, and the mathematical probability formulations from which they are derived, constitute the computational form of induction. But if we take the domain of inductive logic to encompass all instances of reasoning from the more particular to the more general, computational initiatives can properly cover just a portion of it. They can only comprehend, much less formulate, generalizations derived from frequency or density distribution data, i.e., directly empirically-predicated, a posteriori propositions. There is as yet no adequate technical apprehension of how to realize grander generalizations of the Newtonian and Darwinian sorts, despite a century or more of serious attention from some very serious scholars. There is not really even any agreement as to whether an operational inductive logic is even practically reachable.

The most thoroughly explored approach, attempting to develop an inductive analog to deductive entailment, has not been productive. Indeed, it's been deductively demonstrated that an operational inductive logic must involve something more and/or different than simply formally explicating the syntactical properties of the sentences by which premises are converted into conclusions. This raises reservations about the pragmatic purport of the most ambitious attempts along this line, instances of Inductive Logic Programming [10, 11, 12]. The typical inductive logic programming application involves the search for inferences in the form of generalizations derived from an array of empirical referents (data bases or sets of exemplars [13]). But because the inferential mechanism employed in inductive logic programming exercises tend to be merely mapping operators, the conclusions at which they can arrive can be nothing more than a logical consequence of their syntax (mainly in the form of first-order predicate calculus provisions) and the semantic content of the empirical referents they were provided. The
generalizations at which inductive logic programming exercises tend to arrive cannot then be said to represent new knowledge, but merely a transformation (or transmogrification, if you will) of that already incorporated in the exemplars. Nor do the actual accomplishments of inductive logic programming provide much support for its proponents’ contention to have authored advances in machine-learning that now make meaningful Baconian induction possible [14, 15]. Rather, the results that have been obtained might better be taken as evidence that ILP does not enable machines to do inductive inference, per se, but merely an attenuated type of statistical inference and/or another variety of associative inference (qua essays in pattern-recognition).

It’s best then to search for more continent sources of probabilistic support for Type-3 devices. Two such come immediately to mind: Classification and Regression trees [16]. Both can be used to generate prediction-driven decision choices, qualitative and quantitative, respectively; both also are technically familiar (particularly. these days, as adjuncts to data mining applications). Procedures for their construction and employment are well-established [17], and implementation support is widely available (through software schema like CART and DTREG).

Classification Trees are vehicles for assigning subjects to membership in qualitative classes (including fuzzy sets), where the class to which an entity belongs is a function of the values obtained for one or more independent variables qua predictors (which may be either categorical or numerical). They can then be a primary source of decision predicates in situations where the choice of a course-of-action (treatment or response option) is dictated by the particular category into which a subject appears to fall. Though similar in purpose to Discriminant Analysis, classification trees differ in being recursive and hierarchical (characteristics they share, as will shortly be seen, with Type-5 devices). This allows classification trees to deal with predictor variables in isolation, which can sometimes provide more in the way of discriminacy than ordinary linear discriminant analysis. A typical task for a classification-tree based Type-3 device might then be directing the dissemination of targeted-advertisements so that inducements are delivered to those classes of individuals expectedly most well-disposed to receive them.

A Regression Trees is an alternative medium for portraying multivariate regression functions, where the dependent (response) variable is numerical/continuous in character, and predictor variables can be quantitative and/or categorical. The nodes of a typical regression-tree construct might then be formed of simple, univariate relational expressions capturing the character of the influence of a particular independent (predictor) variable on the dependent (response), and perhaps also expressions of covariance or codeterminacy among the state-variables (in emulation of traditional ANOVA/ANCOVA techniques). The path followed through a regression tree, towards a conclusion in the form of a particular projected value, is conditioned by the outcomes of tests conducted at the various nodes. The selection of a particular branch (or arc) radiating from a node can then be made dependent on the value assigned the variables by the local evaluative function. Regression trees commonly generate expectedly dominant conclusions, as distinct from the maximum-likelihood conclusions coming from ordinary parametric statistical inference methods. Among the applications that regression-tree based directive decision devices could handle are those involving forecast-dependent decisions, where decision choices are products of longitudinal inductive inference initiatives, and decision predicates take the form of time-series data. Support for developing/deploying regression trees is available via packages that range from plug-ins like XLMiner to more advanced protocols like MART, and more recently, MARSplines.

3) Algorithm-driven Devices

It is plausible to think of designing a Type-2 device to assume authority over virtually any application where decision choices can be entirely determined by a conventional mathematical optimization method of some kind. Thus, for example, we might configure a directive decision device to assume the role of a dispatcher, providing that the decision responsibilities associated with this position were of the sort that could be accommodated by a linear programming model, e.g., problems of the classical traveling salesman variety. In its usual formulation, a salesman has n customers he wishes to call on during some future period. The typical task for the dispatcher is to devise a routing schedule that will minimize aggregate travel time (which is equivalent to the objective of maximizing customer-contact time). Given inputs specifying the locations of the customers and available connective avenues, and some complement of constraints (time, cost or transport related) that serve to bound the feasible solution space, a linear programming model could be expected to generate an effectively optimal routing schedule in terms of some decision criterion. The salesman would then be 'directed' to abide by this machine-generated schedule.
Dealing with probabilistic variants on the traveling salesman problem would demand the development of a Type-4 device. Such a device might, for example, be tasked with developing routing schedules that maximize the expected value of customer visits. This would demand a statistically-supported scheduling algorithm that would assign a productivity index to each prospective customer, perhaps via formulation of this sort: \[ \Pi e = P\text{(sale)} \times V\text{(sale)}, \] where \( P \) is the probability of making a sale to customer-\( c \), and \( V \) the maximum-likelihood estimator of the value (average yield, or marginal revenue) from sales to that customer. A baseline schedule would then be set so that the highest expected-value visits have the highest priority. The probabilistic dispatch decision would then establish a routing that would expectedly yield the highest aggregate profit impact for the salesman's working day.

What's not so plausible is the prospect of developing directive decision devices to handle more demanding —multicriteria and/or multiobjective— dispatch-related applications. The primary impediment is the absence of any singular instrument that can provide a proper algorithmic solution to such problems (which itself is owing to the absence of any mathematical method for simultaneously optimizing over two or more variables, actually or expectedly). One way around this is to employ multiple models; an \( n \)-factor (criteria, attribute) application might then be attacked by installing \( n \) linear programming models, each targeted at a different criterion and operating under a different objective function. Merely running multiple models does not, however, yield an actionable conclusion. This requires somehow conjoining the results from the several models into a coherent set of decision premises. But there's unlikely to be any computer-executable algorithm that can do this in a satisfactory way (except perhaps for essentially trivial cases, where criteria are few in number and all of the same numerical order, and where the objectives sought are not really all that contentious). Assembling conjunctive solutions is then a task best (if not necessarily) left to human judgment. This means that multicriteria-multiobjective problems will generally need to be addressed in a collaborative man-machine context [18].

The other technical tactic for dealing with multicriteria-multiobjective decision problems is likely to lead to the same end. This calls for exchanging ordinary algorithmic instruments for those designed to comprehend tradeoffs, and so to generate \textit{optima-at-the-margin} resolutions [19]. Some multiobjective problems, mainly those of the simpler sort, may allow a quasi-deterministic solution delivered by Goal Programming algorithms [20], and so would not impose requirements all that much beyond those of more conventional linear programming processes (other than the need for user-supplied numerical weightings). The more capable multicriteria-multiobjective instruments are, however, intended to be employed interactively, as all depend on non-objective decision predicates (fuzzy preference orderings; judgmental, interpretive or otherwise \textit{soft} inputs) elicited from human collaborators [21, 22]. Because this dependency extends beyond merely setting initial search-solution conditions, such instruments cannot be used to provide the technical underpinnings for directive decision devices.

**B. Mid-Range Constructs**

Type-5 and Type-6 devices are node-arc structures configured as manifold network models. They are 'manifold' in the sense that they are comprised of some multiplicity of elementary (algorithmic) directive decision devices. That is, each of their nodes represents a discrete decision point (or requirement), made manifest in the form of a computer-executable algorithmic model. The arcs then serve to establish the pattern(s) of interconnections among the nodes, indicating the order in which the various decision are to be undertaken under which circumstances, and any intersect conditions (in terms of direction and nature of influences and/or passage or sharing of decision predicates, etc.). The resultant relational specifications could be collected into a metamodel, perhaps by employing procedures similar to those used to construct post-semantic Associative Networks [23]. Manifold network models —or, meta models, more correctly— can then conceivably be tasked with carrying out entire decision protocols, and so functioning as managerial vs. merely decision agents.

They are naturally best suited to managing entities that themselves are—or can be represented as— network constructs. This allows for some degree of morphological correspondence between managerial apparatus and subject. This, in turn, may allow Type-5 and Type-6 devices to be implanted, such that their range is roughly coincidental with the domain of the subjects they are to supervise. To operate as managerial agents, the two mid-range devices would need to be able to do their own data-gathering, and so would be the first directive decision devices equipped with endogenous information acquisition provisions. They would also be the first devices to be able to directly implement their own
decisions. It’s then the differences in the nature of their interconnective instruments that determines the applications for which Type-5 and Type-6 devices are suitable.

Given their deterministic connective instruments, Type-5 devices are suitable for supervising systems whose substance can be adequately represented in a recursive model of some kind. Recursive models permit only unidirectional causality and hierarchical impacts. This allows the contents/computations of higher-order nodes to influence lower-order nodes, but not the reverse. Such models are typically formulated as systems of linear (algebraic) equations [24], as with the staple products of conventional econometric modeling exercises [25].

The probabilistic provisions of Type-6 devices can let them comprehend entities or systems constituted as stochastic node-arc structures, where causality is multidirectional (up, down and lateral) and components may indeed be arrayed in reciprocal or otherwise non-recursive relationships (c.f., [26]). To put a quick pragmatic point to this, consider a deterministic and stochastic variant on one of the most common classes of network-type tasks, Traffic Management.

Regulating road-based transportation networks, where intersections constitute nodes and avenues are arcs, is a task for which a recursive construct, and so a Type-5 device, should be appropriate. The typical implementing tactic is to equip each intersection with a set of computer-controllable traffic lights, linked to sensors that can read current loadings (e.g., numbers of cars passing through an intersection in a given direction in a given cycle, number of vehicles backed up waiting for a green light). These provide the prerequisites for a recursive-centrifugal traffic management scheme, whereby higher-order nodal algorithms determine the timing-duration of traffic lights at all downstream intersections, based on the current assemblage of data from its own and subordinate sensor stations. This allows the opening or closing of alternative avenues, and hence the dynamic reconfiguration of the road network, in response to currently-prevailing travel patterns. In recognition of the federative character of most recursive-centrifugal systems, each intersect would retain the right to employ its own nodal algorithms to handle cross-traffic, or to accommodate vehicles moving other than in the generally prevailing direction. Moreover, the entire system would likely revert to a decentralized regulatory scheme, where each node recognizes and reacts only to local loading conditions, during non-rush hour intervals.

There are, of course, other traffic-management type missions that are obvious applications targets for recursive composite constructs, e.g., Routing vessel traffic in and around seaports (with differently formulated nodal algorithms applying to the regulation of shipping lanes and allocation of docking facilities, etc.); choreographing landing and takeoff patterns at airports (where disparate nodal algorithms would be used to regulate utilization of approach spaces, taxiways and apron areas, and also to manage operations under routine vs. high-utilization or emergency conditions, etc.). Somewhat less obviously, recursive computational networks can also be posed as the technically preferred medium for regulating centrifugal switching systems (message propagation, distribution of fluids via pipeline complexes, etc.) and a variety of sequencing-scheduling tasks (such as determining work-flows in project management exercises, production flows in job-shops or material flows as an aspect of supply chain management).

Indicative of the somewhat more exotic traffic management tasks that probabilistically-instrumented composite constructs can be assigned, there is the smart elevator system. This is widely counted as a practical success for neural-networks. Strip them of their interesting but unnecessary biological pretences (their claim to mirror the morphology of the human brain), and neural-networks reduce to nonhierarchical node-arc constructs that can be tuned to comprehend, and thereby perhaps also control, non-recursive intersects among a set of system components [27, 28]. Hence their triumph in terms of the smart elevator system, where the primary technical challenge was to maintain an adequate degree of congruence between the pattern in which elevators are deployed, and projective passenger demand patterns.

Portrayed in network terms, an elevator system is a grid (lattice-like) structure, with as many intersections —qua minor nodes— as there are floors and elevator shafts (vertical corridors). Each of the elevators would then serve as a supra-node, with its actions regulated by a local algorithm (or set of such) that is cognizant of the intended actions of the other elevators in the system. Regulatory authority is thus distributed more or less symmetrically among the components of the system. The arcs in the elevator system are now taken to represent variables (or vectors of variable length, if you will) rather than structural constants. A deployment decision for an elevator thus defines an arc that specifies a schedule of intersects to be serviced (i.e., which floors it will stop at), with these decisions conditioned by three factors: (1). The projective demand pattern currently in place, which determines the initial or starting-state positions for the several elevators; (2). Actual service requests, which may be either internal (a call for a stop by a passenger already aboard an elevator) or remote (where a prospective passenger on one of the floors pushes an UP or
DOWN button); though internal requests will normally take precedence over remote calls, neither comes in the form of a command that an elevator must obey; and (3). The servicing schedules currently proposed by all other elevators, such that all deployment decisions become codeterminate. The desired result is that each of the elevators will set itself to respond to those requests/calls for which it is best positioned, and so make its contribution to the best performance of the system in aggregate.

There are a number of other applications where stochastic network management constructs might be expected to obtain similar results, some of which are of much greater moment than the smart elevator system. Such constructs might, for example, serve as the centerpieces of a long-awaited, deliberately decentralized air traffic management system (if only to mitigate the threat posed by the upcoming age-mandated retirements of so many human controllers). They might well also prove to be the most technically attractive answer to the problem of maintaining the integrity of decentralized power grids, i.e., maintaining dynamic equilibrium between supply and demand, while at the same time guarding against ill-considered local decisions that can concatenate into massive rolling blackouts [29].

There is, however, this closing qualification: If it is to underlie a directive decision device, a neural-network construct must be capable of unsupervised pattern recognition. Though it may start life with a set of imported patterns, thereafter it must let patterns emerge as a function of natural usage. Several distinct demand patterns might emerge in this way for an elevator system: Clustered at the beginning and end of workdays (or for special events such as evacuation drills), stratified during intervening working hours, sporadic on weekends, etc. Were each of the recognized patterns considered to represent a system state, the overall dynamics of a smart elevator system might conveniently be recast in Markov-type terms, with the focus on state-transform probabilities qua expected patterns of succession among patterns.

C. Control System Constructs

The last two prototypes are configured as more or less full-blown process control constructs. As per Illustration 3. As such, they will typically be tasked with keeping some parameter(s) of interest within a tolerable range of values, or minimizing deviations from some desired operating value.
Both Type-7 and Type-8 devices must then be self-triggering, have their own data-capturing capabilities and, in their usual deployments, will be equipped with embedded actuation mechanisms, i.e., some type of apparatus that allows them to directly execute (rather than merely direct the enactment of) their corrective or remedial decisions. The decisions at which they arrive will take the form of corrective actions generated by a control function qua rectification algorithm(s). Thereafter, as with the other prototypical devices, instrumental differences come into play.

Type-7 devices are analogous to conventional first-order control systems, and so can make only after-the-fact corrections via deterministic rectification algorithms. In cases where a control function is set up to institute corrections in an amount proportional to the magnitude of the deviation, a Type-7 device would constitute a servo-cybernetic control system. Applications for such constructs range from relatively pedestrian tasks like enabling antiskid systems on automobiles, to complex challenges like providing the technical wherewithal for the fly-by-wire flight-directors installed on modern high-performance aircraft.

As for Type-8 devices, their probabilistic underpinnings not only make them capable of controlling stochastic (moderately stochastic, anyway) processes, they also allow for an anticipatory orientation. That is, while Type-7 devices predicate their corrective actions on a point-in-time parameter values for process variables, those instituted by Type-8 devices are taken in reflection of an array of projective values for process variables. This, in turn, means that they can be equipped with second-order control algorithms, focused on the second moment —accelerative or decelerative properties— of the projective functions for the process variables of interest. A Type-8 device would then be the generally preferred technical choice to control processes centered on rate (vs. stock) variables, e.g.: The rate at which some quantum of a resource is being consumed (fuel management systems for vehicles; dynamic inventory replenishment protocols); rates of closure/separation (docking control systems for marine vessels or spacecraft, positioning of fuel rods in nuclear reactors or electromagnets in high-mass motors); rates of directional movement, or velocities (re: post-inertial navigation aids, vectoring of interceptor aircraft or auto-tracking telescopic arrays); rate regulation for implanted drug (e.g., insulin) delivery systems; reaction control apparatus for volatile chemical manufacturing processes, and the like.

With such missions in mind, Type-8 devices require, uniquely among directive decision devices, a capability for in vivo outcome-assessment, such that the consequences of the corrections effected by the second-order control functions are regularly weighed against expected or desired effects, with disparities occasioning algorithmic amendments. Type-8 devices are then also unique in that they have adaptive capabilities that mark them as kin to higher-end cybernetic-inspired process management constructs.

EMPLOYMENTS AND EXEMPLARS

Recall the earlier argument that directive decision devices tend to be deployed in one of four basic mission/tasking categories: (1). Executory: Designed as a substitute for a human decision-maker(s); (2). Compensatory: Assigned responsibility for certain aspects of an operation or process for which human functionaries are assumedly less well-qualified; (3). Interdictive: Delay implementation of potentially injurious actions until authorized by a designated superior authority to allow their execution; and (4). Cooptic: Assume control in cases where human functionaries have failed to initiate an appropriate/timey response to a potentially perilous situation. The first of these categories is currently —and likely to remain— the most well-populated, as Executory devices are most likely to be configured as elementary constructs, and so the easiest to conceive and create.

Executory Devices

There are principally three reasons why an organization might decide to deploy an executory device. The apparently most popular of these reasons is the expectation of economic advantages. These are available in cases where a computerized agent is presumed able to make decisions more cheaply than, and not materially worse in quality than, a human functionary. An Executory device would then be a potentially attractive investment in cases where the costs associated with its construction and operation are projected to be more than offset by the reduction in labor costs realized by the release —demotion, reassignment or removal— of the individual(s) previously charged with responsibility for the decisions at issue. Thus, for example, the development of computer-based constructs capable of making navigation-related decisions has allowed some airlines to remove the third member from their cockpit crews. Similarly, insurance
Compensatory devices are designed to undertake activities that require capabilities that humans —in general or particular— may not have in sufficient degree. Where deficiencies are physical in nature, such as shortfalls in motor skills or perceptual sensitivities, compensatory devices will appear mainly in the form of mechanical constructs engineered to execute sensor-determined actions, e.g., robotic surgical instruments, automated agricultural machinery (self-steering row crop cultivators, say), computerized piloting apparatus for inherently unstable high-performance aircraft, and a host of more mundane artifices like the modern engine control systems that can recognize, and finely correct, minor departures from optimal operating conditions that would be beyond the ken of even the most sensitive professional drivers.

Compensatory directive decision devices, on the other hand, are targeted at analytical rather than physical shortfalls. These would then be targeted at decision situations where the quality (rectitude and exactitude) of decision choices is strongly dependent on certain technical skills or sensibilities in which a human decision-maker may be deficient. In the typical organizational setting, what human functionaries are most likely to lack is a sufficiency of quantitative skills or mathematical sensibilities. The typical compensatory device will then be algorithm-driven, deterministic or probabilistic, with its exact algorithmic apparatus a reflection of the character and complexity of the computational requirements inherent in the decisions to be made. In any specific decision instance, what a compensatory device is called upon to do should also be a reflection of the strength of an individual's capabilities or, conversely,
the degree to which a human functionary is deemed/demonstrated to be deficient with respect to some
decision requirement. Well-designed compensatory devices should be equipped with a front-end facility for
assessing the capabilities of the person(s) having nominal responsibility for a decision. The results of this
assessment would determine the extent of the technical authority the device will assume (or be allowed to
assume, rather) in the situation at hand.

Some compensatory devices will have been developed in response to the volume and/or
complexity of the calculations required to arrive at proper decision choices. In cases where the bulk of the
burden is in the sheer volume of required computations, as it is with many financial applications and
tactical management functions, elementary algorithm-driven (Type-2 or Type-4) devices will probably
serve well enough. Where the analytical challenge comes mainly from mathematical complexities, the
greater resolution power of computational network constructs might make a Type-5 or Type-6 device the
generally more appropriate technical choice (as with some of the recently-evolved automated workload
managers for computer systems such as IBM's eLiza or Project Oceano for Linux servers).

One application that nicely illustrates this instrumental progression is the problem of determining
optimal static weight-and-balance solutions for commercial aircraft. Once left to flight personnel and slide-
rules or hand calculators, responsibility for this function is now more often invested in a Type-2 device
running on a lap-top computer. The computational challenge, however, would be much increased were a
directive decision device to be charged with making dynamic (in-flight) weight-and-balance decisions. This
would require it to take more or less constant account of things like running reductions in residual fuel
levels, or changes in flight conditions that might call for moving the pivot point more fore or aft, etc. The
sharp increase in computational complications that accompany a shift from the static to dynamic variant of
this problem would likely require a corresponding shift from an elementary Type-2 to a more powerful
Type-5 compensatory device. As a kindred but not so formidable application, airlines, hotel chains and car
rental companies seem to have some interest in converting from fixed-rate to dynamic pricing. As the latter
requires rates to be regularly recomputed in response to any changes in projected demand levels or
occupancy rates, dynamic pricing decisions are probably beyond the capability of most reservation agents,
but well within those of Type-3 (regression-tree centered) or Type-4 (statistically-instrumented) devices.

Other compensatory devices will owe their development less to any computational complexities
associated with the decision at hand than to shortfalls on the human side. Consider, for instance, the
problematic provenance of the computerized income tax preparation programs so popular in the United
States. Though mainly marketed as a response to the intricacies of the US Tax Code, most of those
purchasing them will have only relatively rudimentary tax issues to resolve. But most of those purchasing
them will also have only the most rudimentary of arithmetic skills. The better part of the demand for these
packages is assumedly then due to the typical American tax-payer's inability to carry out the simple ratio-
based or ordinary algebraic calculations that may be required of those filing long-form returns (to properly
figure income-proportional deductions and depreciation allowances, etc.).

Analytical deficiencies are of rather more consequence when they affect those occupying
managerial positions who, after all, are employed to make decisions on behalf of others. Of the decision
responsibilities devolving on managers, the most ubiquitous and generally materially significant is that
requiring the rational allocation of scarce resources. What allocative rationality requires is that resource
disposition decisions be allowed to benefit from all the scientific (formal analytic or algorithmic) discipline
they deserve, or that they will tolerate. This latter qualification recognizes the possibility that some
allocation decisions — particularly those reserved for higher-order managerial operatives — may be of the
grand guns vs. butter variety, or otherwise of a type for which there is no ready technical solution, and so
beyond the purview of any compensatory directive decision device. Most allocation decisions, however,
and certainly most of those for which middle or lower level managers are likely to be held responsible, will
indeed allow a technical solution.

But many members of the contemporary (American especially) managerial corps may have so
little in the way of mathematical aptitude that they cannot be relied on to provide allocation decisions with
all the discipline and precision they deserve. Nor is there much prospect of improvement here, as witness
the steady decrease in the Management Science share of the curriculum in the typical U.S. business school
or public administration program. Where there are reasons to doubt (or, alternatively, no reasons not to
doubt) a manager's ability to bring the requisite level of technical attention to a decision situation, a Type-2
or Type-4 device might be developed to do so. Or, by way of a somewhat more circumscribed charge, a
compensatory directive decision device's authority might be restricted to the technically-sensitive aspects of
a decision situation, and the manager commanded to abide by the machine's dictates in their respect.
Some mention also needs to be made of Electronic Performance Support Systems [30, 31]. What's typically claimed is that, when equipped with an EPSS-type construct, less well-trained and experienced workers can perform certain quasi-professional functions as well as employees with considerably more schooling or practical experience [32]. This begs the question of whether EPSS packages are better counted as Executory or Compensatory devices. In favor of the former is that if they can allow the displacement of more highly-seasoned, and thereby more expensive, employees by novices, EPSS constructs can generate economies in the form of wage savings. But the case for their inclusion among Compensatory devices is a bit more compelling. If an EPSS is to be of any positive practical value, it must be able to effect higher quality decisions than presumably would have been made in its absence. The only way it can do this is if it's equipped with more in the way of quantitative capabilities, or with a higher level of technical intelligence, than the individual novices brought under its command.

In any event, man-machine interactions involving an EPSS—or, for that matter, any compensatory directive decision device—cannot be considered collaborative by any stretch of that term. It's more like a morganatic marriage, with the man being the decidedly inferior member.

**Interdictive Devices**

The basic change for interdictive devices is to prevent prospectively harmful decisions from being enacted. The more costly the prospective consequences of a decision error, the more compelling the occasion for an attempt to develop an interdictive device. As with compensatory constructs, Interdictive devices can be mechanical artifices. These will typically be intended to prevent actions that may be injurious, or even fatal, to the individual taking them. Anti-lock braking systems, for example are meant to preclude the instinctive human tendency to over-brake in response to skids or impending collisions, an action more likely to exacerbate than avert whatever peril inspired it. The Stall-Spin Savers now installed on some airplanes are also there to try to protect humans from taking instinctual actions (trying to correct a stall by forcing the nose of the aircraft upwards) that will most often transform a recoverable irregularity into an irrecoverable disaster. Some interlock-type mechanisms can also be counted as compensatory devices, like the breathalyzer-equipped ignition systems that disallow alcohol-impaired drivers from starting their automobiles, or governors that prevent operators from over-accelerating or over-working their vehicles. These mechanical devices generally cannot be disabled or overridden by the individuals immediately affected (though some can be remotely shut-down or readjusted by superior agencies).

If most interdictive mechanisms are intended to protect individuals, the interdictive variants of directive decision devices are most often deployed to guard institutions against injudicious decision choices on the part of its constituents, or advertently injurious initiatives of either internal (e.g., sabotage) or external authorship. Some interdictive-type devices can do both. The primary rationale for programs designed to detect stolen credit cards (by examining usage patterns for anomalies) may be to limit the financial damages to the issuer, but they are also of benefit to card holders. A drug store chain that requires its pharmacists to use a program that checks for adverse drug interactions before filling prescriptions might mainly be concerned with averting legal or reputation-related damages; but it clearly serves the interests of its customers as well. As yet another example, both institutional and individual benefits would follow the development of a device that could 'interdict' erroneous targeting decisions that would otherwise cause unintended civilian deaths (often dispassionately dismissed as collateral damage) or, even more mortifying to military commanders, causalities caused by friendly-fire.

For institutions, anyway, interdictive directive decision devices are another species of risk-management implement, as per this typical tasking: Defeat attempts by organizational constituents, individuals or units, to implement any courses-of-action that an interdictive device recognizes as potentially harmful, unless/until it's approved for execution by a designated managerial superior (the obvious qualification being that the only actions a directive decision devices can interdict are those that depend on a locally-controllable computer for their enactment).

One way of enabling a device to recognize prospective perils is to have it examine an action for any clues that might mark it as a member of some class of well-defined threats, e.g., instances of industrial espionage, fraud, sabotage, regulatory violations, lapses of quality control, or the more blatant varieties of professional ineptitude or managerial malfeasance. Interdictive directive decision devices will then probably most frequently be configured as precursor-driven Type-3 (classification-tree) type constructs, centered on a sequence of threat-assessment (problem-recognition) procedures something like these:
• **Defined-Threat Set**: \([T_1, T_2...T_n]\), where the \(T_i\)s represent predictable (empirically-precedented, notional or logically possible) perils or classes of such;

• **Precursor Array**: \(W \times [C_1, C_2...C_m] \Rightarrow T_i\), with \(W\) being a categorical weighting operator (high, low, etc.) and \([C]T_i\) a set of (one or more) events/circumstances which, should they occur, would be indicative of the existence or emergence of threat \(T_i\).

• **Threat Recognition**: \(\{O\} \rightarrow V x [C_1 \cap C_2 \cap ...C_m]T_i \rightarrow P(X\in T_i)\), where \(O\) is an array of current precursor-pertinent observations, \(V\) is an operator expressing the observed strength, or level of activity, for each of the precursors in \([C]T_i\).

This latter would underlie a current estimate of the probability that the action of interest \((X)\) is a member of (or variant on) threat-set \(T_i\). If action-\(X\) is so recognized, the interdictive device would first do whatever is necessary to avert its immediate execution by any of the organization's own or affiliated computers (by, for example, keeping it from entering the job queue of an implementation program, or sequestering it in an area accessible only to the interdictive device itself). Secondly, it would alert an appropriate higher-echelon authority of the situation, and await a command to enable, table or disable the suspect course-of-action.

Hence the prospects for an interdictive device directed against perhaps the most virulent threat to retail banking institutions: Reducing their vulnerability to fraudulent wire transfers. An assemblage of precursors would include both empirical (previously observed and/or occurring elsewhere) and notional (possible and plausible) indicators of possible fraudulent intent on the part of bank functionaries, or intruders posing as such. Of most benefit would be a master precursor array, maintained centrally (by the American's Banker's Association, say), that all banks could both address and amend. Two interdictive tactics are available, a reactive and anticipatory approach.

The reactive approach would have a device await the appearance of a wire-transfer request. It would then look back along its trail in search of any indicators (via evidence of events or initiatives on the industry master precursor list) of possible criminal intent. In the absence of any such signals, the device would allow the wire transfer to proceed as requested; otherwise, it would be intercepted and held pending a decision by the higher-echelon executive to whom the case was forwarded. A reactive interdictive device might also be set up as a *method-audit* mechanism. Method-audit mechanisms attempt to reconstruct the provenance of a proposed course-of-action in the hopes of avoiding inadvertent threats, i.e., decision choices that may prove inefficient, ineffectual or even dangerously dysfunctional due to certain flaws—procedural, evidential or instrumental—that might have demeaned the decision process from which they were derived. So, upon the appearance of a wire-transfer request, a method-audit based device would also look backward. But instead of searching for signals of sinister intents, it would go though a checklist electronic of procedural do's and don'ts for handling wire transfers. Any irregularities would then be flagged for review elsewhere, and the wire-transfer held in abeyance pending a determination as to its fate from a higher-order decision authority.

Under an anticipatory tactic, an interdictive device is always at work in the background, actively searching for evidence of prospective threats. To that extent that larcenists telegraph their intents, an interdictive device could double as a kind of early-warning system. That is, when the evidence suggestive of an impending fraudulent initiative is sufficiently strong (in terms of the number and/or intensity of active precursors), the device may decide to alert an organizational authority of in advance of an actual funds transfer request. But this begs a deployment-related question for which there's no generally satisfactory answer: Should the existence of an interdictive device be made known to, or kept invisible to, those on whom it might be visited? Making them known may possibly discourage some injurious initiatives from being mounted in the first place. On the other hand, broadcasting their existence may merely invite ingenious souls to figure out a way to subvert them while irritating innocents. Or maybe the best advice is this twist on an old security trick: The only time you want to advertise the existence of an interdictive directive decision device is when you do not actually have one!

**Cooptive Devices**

Cooptive devices are mainly crisis-management implements. They stand ready to take command in critical situations should humans falter by failing to institute a prescribed (per administrative fiat or
doctrinal dictate) remedial action in a timely way. In crisis-management contexts, the timeliness of a
response may be determined with reference to a fixed instant in the form of an absolute action threshold.
This establishes the last possible point in time where any sort of solution is available. Once an action
threshold is passed, a crisis is no longer containable; whatever adverse consequences a problem portends
are thereafter inescapable. Given this tasking, cooptive devices first need to be able to access and assess the
circumstances around them, looking for those that might signal the emergence of a situation where their
intrusion might be required. Should such a situation arise, and should the requisite response not otherwise
be forthcoming, a cooptive device needs also to be able to exercise whatever physical power is required to
successfully wrest control from any entities (men or machines) that might resist it. Thereafter, of course, it
must have the mechanical wherewithal to see that the called-for remedial action gets put into execution.

What seems to be the signature application for cooptive devices is collision-avoidance. Some
collision-avoidance situations will be well enough served by elementary cooptive devices (e.g., the system
on railroad trains that will automatically stop a train three minutes after passing a warning signal, if the
engineer has not already done so). Other, more advanced applications will require cooptive devices fitted
out as full-blown process control (Type-7 or Type-8) constructs, as with those, for example, that might
anchor next-generation Traffic Alert and Collision Avoidance Systems, or TCASs.

Aimed at averting mid-air collisions, one vision of how TCAS might operate would equip
aircraft with a novel type of sensor: A configuration-sensitive radar unit that would emit a conical beam
whose geometric properties reflect the performance potentialities of the aircraft in which it's installed. The
projective length of the conical beam would be greater the higher the true air speed (current or fed-forward)
for the host aircraft. A modern jet airliner is then expectedly going to have a more extensive forward
projection than a vintage prop plane. The cone's opening angle will be inversely related to the aircraft's
maneuverability. The greater the maximum stress its airframe can withstand, the higher its permissible rate
of climb or the more radical an accelerated diving turn it can safely execute, etc., the smaller the diameter
of the cone at all working projection lengths. Thus, the conical signature for a Fighter-Interceptor is going
to be far narrower than that of a lumbering passenger liner.

What excites an XTCAS device is then the prospect of a midair collision, signaled by the
intersection of two (or more, for that matter) conical projections. The greater the relative areas of the
intersect(s), the higher the imputed probability of a collision. An initial critical time threshold is then
established by carrying forward the current aircraft headings and speeds, and figuring in the
maneuverability capabilities of the aircraft (as a function of the morphology of their projections). This
threshold is the last opportunity for either aircraft to forestall a collision by executing an evasive maneuver
at the very maximum of its capabilities. Radar contacts would routinely be presented as data to the Flight
Director System (or autopilot) that's responsible for most regular en-route airplane operations; the pilots
would be given both a visual and auditory alert to the non-routine prospect of a collision. If then, for any
reason, neither the flight director program nor the pilots initiate an appropriate course alteration before the
threshold is reached, the XTCAS device takes command of the controls and executes an emergency
operation. This emergency maneuver is best standardized for all aircraft (e.g., a diving turn to starboard), as
this obviates the need for coordination among devices. That this XTCAS scheme requires only one cooptive
device means it can apply to pretty much any type of vehicle and category of impact, including stationary
obstacle-clearing applications.

The XTCAS-type device envisioned here is obviously an implement of last resort. Far better to
take a leisurely approach that has projected intersects gradually contracted until a collision is no longer a
threat. No airline, certainly, wants to put either its passengers or its planes through the stress of maximum-
capability maneuvers. But it's this very reluctance that provides the rationale for XTCAS-type cooptive
devices. The typical Flight Director or autopilot is programmed to make a multitude of tiny corrections in
the interests of both passenger comfort and fuel economy. Pilots pride themselves on their finesse, their
gentleness at the controls, and their ability to avoid any abrupt corrections to course or attitude. XTCAS
cooptive devices would have no such compunctions.

Cooptive devices will not always be unwelcome. It's possible to think of some sorts of decision
that people might actually wish were covered by a cooptive device. They might, for example, be designed
to relieve humans of the responsibility for dealing with the most distressing of decision situations: Those of
the Hobson's Choice variety, where the only available options are all equally unpalatable, e.g.: 1). A
submarine has struck an undersurface object, piercing its hull. Unless the damaged compartments are
sealed immediately to contain the flood, the entire ship is in peril. There are, however, crewmen in those
compartments. Closing the watertight doors means their certain death. 2). There's been a leak in a
biological laboratory handling dangerously toxic disease agents. The proper response is to destroy the lab to preclude the possibility of a release that could cause widespread harm. But destroying the lab means losing data and research materials that could compromise, or perhaps even cripple, the careers of the lab's personnel, and a substantial loss, in terms of both capital and repute, to the institution of which the laboratory was a part. 3). The most awful of the decisions a human might be called upon to make would be whether or not to launch a retaliatory nuclear strike in response to an indicated nuclear attack on one's own country. This is something that not all people can be relied on to do, irrespective of the power of the proofs. Yet the belief that political authorities, submarine commanders and missile silo supervisors would actually do so was critical to the integrity of the MAD (mutually assured destruction) doctrine; and this, of course, was conceived as the critical deterrent against a nuclear conflict. So it was that the two principal participants in the cold war, the US and Soviet Union, both carefully seeded the suspicion that their nuclear retaliatory capability was ultimately in the hands of a computer program.

Faced with true quandaries like these, even the most stalwart or stoic humans are likely to hesitate; and many, maybe, might be visited by a kind of practical paralysis, not unlike the proverbial donkey that starved to death because it could not choose between two bales of hay. But if people would suffer over such choices, a dispassionate directive decision device would remorselessly, and immediately, decide in favor of whatever it’s been programmed to recognize as the doctrinally-proper response. After all, as Macbeth would have it: *If it were done when t'is done, then 'twere well it were done quickly.*

**A QUICK CONCLUDING CONSTRUCT**

When assayed against humans as decision agents, directive decision devices are more dogged, dedicated and undemanding. They are immune to both insult and blandishment, and so can be neither intimidated nor corrupted. They are uncomplaining and compliant, inextricably bound by their brief, and so incapable of having any interests at odds with those of their employers. Tirelessness, obedience, malleability, consistency and economy; these are the abiding virtues of directive decision devices.

These characteristics are enough, certainly, to account for the impressive array of decision responsibilities with which directive decision devices have been invested, as per *Table 3.*

<table>
<thead>
<tr>
<th>Table 3: Applications Tableau for Directive Decision Devices</th>
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<tr>
<td><strong>Elementary</strong></td>
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<td>Categorical</td>
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<td>Compensatory</td>
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<td>Interdictive</td>
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<td>Cooptive</td>
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The entries in Table 3 are also reflective of a key introductory argument: The domain of directive decision devices is restricted to essentially technically-tractable decision situations. Again, what this comes to mean is that directive decision devices cannot—or ought not—be held responsible for decisions that depend more on discernment than mere discriminacy, or where inspiration, imagination or intuition are in demand.

If then there's anything deserving of regret about directive decision devices, it's that there are apparently so many applications open to them...so many human employments that require so little in the way of uniquely human intellectual endowments.

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