FINANCIAL PLANNING USING A NEURAL NETWORK

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ABSTRACT

Financial planning, as an exercise involving synthesis of a solution from standard components, has proved too difficult for knowledge based systems. Approaches that work from records of previous decision making have more potential. In one approach to case based planning, an expert has to specify groupings of situational features and stereotypical financial objectives. These groupings (goal functions) are then related to solutional elements. The process of forming goal functions is difficult because experienced planners work from the whole of the investor profile and provide solutions to objectives which are not even specified. We are taking a hybrid approach to financial planning in which, instead of goal functions, relationships between objectives and situational features (and their relationships to cases) are 'discovered' at a *sub-symbolic* level.

We use an interactive network with three layers of nodes connected by bidirectional links. The initial weights of the links are derived from a normalised frequency of occurrence measure, enabling the network to be built rapidly. The layers correspond to primitive situational features, stereotypical objectives, and the cases containing the financial products forming elements of the solution set. Conceptual analysis shows that any direct statistical relationship between said situational features and objectives is largely spurious. Therefore, there are no direct links between nodes in the situational feature layer and the objectives layer.

1. Introduction

Most people will be familiar with some aspects of financial planning, at least personal financial planning or its specialist areas such as estate planning. The constant entreaties in advertisements coupled with the exhortations in the financial pages of newspapers have served to raise awareness of the benefits of planning for the future: for retirement, for death, for children's education, or simply to avoid paying more tax than is necessary within the letter of the law. Businesses also carry out financial planning: to minimize the tax on income from the return on investments or capital gains; to ensure that money is available for new ventures; to plan affairs so that foreseeable liability may be paid off; and so on. The term 'financial planning' is often used in a loose sense to add status to advice concerning a narrow aspect of a person's or business's financial situation ('investment advice'). Even more confusingly, it is often adopted by those who are doing little more than selling one or more of a limited collection of financial products ('product selection').

We are concerned with the activity of assembling or synthesizing a comprehensive solution to meet the whole of, or a distinct but substantial part of, a person or business's financial objectives; with reorganization of existing affairs as necessary.

2. Financial Planning

Financial planning, variations such as estate planning, capital gains tax planning and portfolio construction, are available from sources such as CPAs, attorneys, solicitors and specialist financial planners. Some commercial banks also provide this service, in the contemplation of obtaining (or keeping) investment related business for themselves or trusteeship for an associated corporation. Other financial services institutions, such as insurance companies and mutual fund organizations, are increasingly becoming involved in this area. Generally, their aim is to sell their own products on the back of any (re)arrangements recommended. Insurance policies in trust or as gifts have long been used to mitigate estate taxes liability. There is tremendous interest in systems that can assist personnel in performing to a level that otherwise might require prolonged training and experience. It is hoped that computers will help to ensure that the standard of service does not fall below the requisite level, for legal liability for performing such an undertaking in a negligent manner can be substantial; moreover, regulators can suspend authorizations, with catastrophic consequences.

Financial planning has proved a difficult area for knowledge-based systems to tackle; unlike the case for applications involving financial product selection or investment advice. In the case of personal financial planning – financial planning in businesses is similar, only a little simpler because the time scales are shorter – the *objectives* which must be achieved are like the following:

- Estate insulation by insurance against disability, illness, etc.
- Provision for dependants in case of death.
- Generation of income from assets to cover normal expenditures or for specific purposes.
- Deferring the imposition of tax on capital gains.

The major difference from the current knowledge-based systems, which give advice on isolated areas, is the high degree to which financial planning objectives may interact or conflict. The fact that existing affairs could not be significantly rearranged attenuates the complexity when service is confined to investment advice. The financial planner is charged with not only allocating the fresh assets to be invested but, potentially, but also altering the existing state so as to contribute to the achieving of the objectives. The planner cannot ignore a less than satisfactory arrangement resulting

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from a clash of objectives, saying that it is out of his brief.

In knowledge-based systems terms, the problem as characterized above is an exercise aimed at *transforming* one state of affairs into another, more appropriate one, by searching through a large space of possible solutions, only some of which are efficacious. Financial planning is a little different from planning in the AI sense, it is more akin to the process of *design* by assembling standard components or components that themselves require minimal design[2]. The importance difference is that, *in practice*, the final design is quite useful even without explicitly ascertaining the interim steps taken to get there. The users can be expected to fill the gaps themselves. As such, a design system, at least in the financial advice domain, can virtually ignore the temporal or ordering element. The basic problem faced by a computer system when creating a design is that, having proceeded down a particular track, it may find that a constraint has been violated, causing it to backtrack and try another path to search. The problem, when approached as a first principles state space search, is thought to be computationally intractable. The system may well have knowledge regarding how to correct or *fix* the violation of any constraint. But the fix may cause some other restriction to be breached, leading to backtracking again.

3. Financial Planning and Case Based Design

Case-Based Design (CBD) is founded on the premise that by working from existing designs, a designer is able to work in the absence of a complete model of the domain. Perhaps the most important part of a CBD system is to classify and index the cases for efficient retrieval on some assumption of the likely problem cases which will be encountered. Cross-indexing is needed to allow directed search and enable inferencing. It is then necessary to retrieve the candidate or target cases based on the classification and the retrieval indices. Similarity with the test case then has to be evaluated.

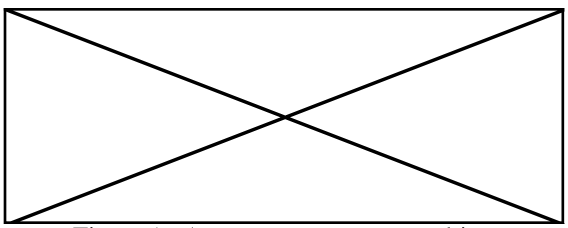
Figure 1 A case as an aggregate object

Most approaches to CBD index cases on the basis of what are called 'goals'. The indices are created by a knowledge engineer on the basis of his appreciation of what the relevant features of a case are and how they are related. There are significant limitations in this approach. The primary limitation is that it is assumed that the judging of similarity between two situations or cases is a simple process: consisting merely of identifying *beforehand* what the relevant attributes are and then just comparing them. However, often one does not know what the relevant attributes are until the cases that are to be compared have been chosen. In other words, the process is circular, if a symbolic processing approach is taken. Our work here attempts to break out of this vicious circle by foregoing the manual identification of relevant attributes of cases. Instead, we rely on sub-symbolic processing to relate cases to each other. The financial planning system, which is based on an object-oriented paradigm, is being developed at the Centre for Computers in Law and Finance, Brunel University. Below, in this paper, we will concentrate on the neural network which is being integrated with the object-oriented system. The purpose of the neural network is to index all the cases and allow the retrieval of those which are, in some sense, 'similar' to the problem or test case. (After retrieval by the neural net, the object-oriented system will use symbolic processing to determine the financial plan). The conceptual representation of the case, as an object, is shown in Figure 1. Each case in the case-base (that part of the knowledge-base which represents each case as a discrete unit) consists of:

(a) The relevant situational features.
(b) The objectives of the client.
(c) The solutions or recommendations that are said to have achieved the objectives.

[2]Variation in the allocation of the amount to different products in the solution set is, strictly speaking, not design, provided it is kept within the governing limits. Violating the limits, if any, would change the character of the instrument. For example, when the contributions to a retirement plan exceed a certain proportion of the income, tax relief is no longer available. We are not concerned with the very top end of clients for whom attorneys and accountants create novel tax shelters.

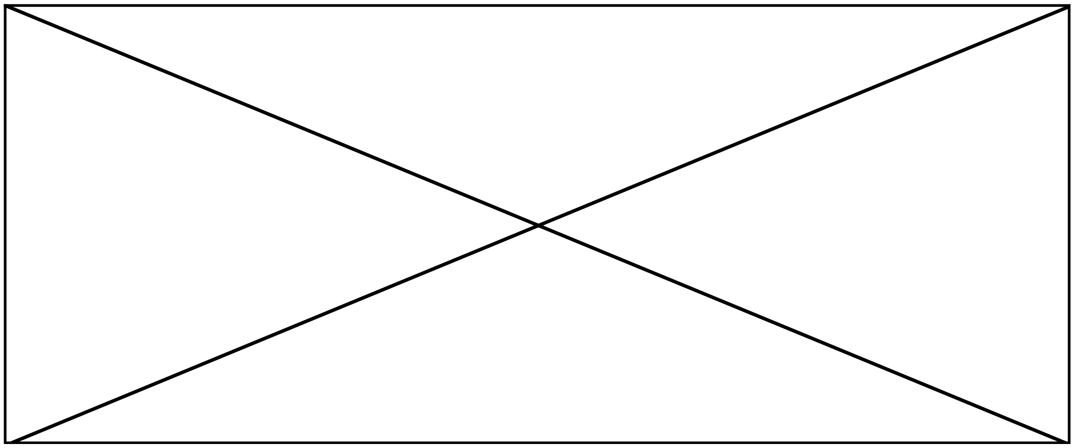

Figure 2 Situational features

4. Situational Features

Semantically, situational features denote that information about the client or the environment which provides the context for the financial-legal design. Examples of situational features are: age, sex, marital status, income tax band, accrued capital gains tax, inflation rate, etc. In the *case*-object, each situational feature is an instance of class objects which are arranged in a hierarchy, a portion of the hierarchy is shown in Figure 2.

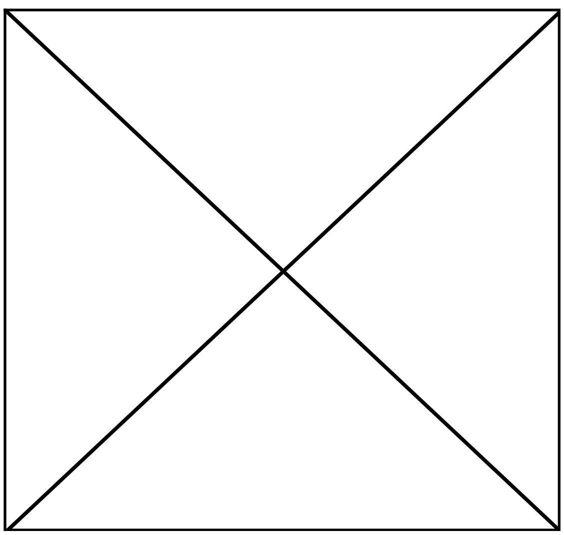

Figure 3 Situational features

5. Objectives

Objectives are financial-legal cliches or stereotypical, high-level aims that the client (or the client's adviser) wishes to be achieved. Examples are:

- achieve security of investments
- defer capital gains tax liability
- provide for family when breadwinner dies
- provide for payment of inheritance tax liability

6. Solutional elements

By solutional elements we mean those financial products or financial–legal devices which are recommended in order to achieve the objectives of the client. These are the standard components of which the financial plan is constructed. The precise mix of the solutional elements will be determined by the scope of the service and the market stance of the particular organization using the system. An example of how these primitive concepts may be hierarchically arranged is given in Figure 3.

7. Neural network structure

The structure of the network that we are using is shown in Figure 4. All situational features are made units in the first layer of the network. All objectives are made units in the third layer of the network. All cases are also units, and form the second layer of the network. Every situational feature and every objective has a non-zero bi-directional link to each case in which it occurs. The weight of each link depends upon the degree of 'significance' attached to the occurrence of the situational feature or objective (we will refer to both as 'factors' subsequently) in the case. A factor which occurs in all the cases within the set has zero significance, while a factor which occurs in only one case is completely significant, which will cause a link of weight 1 to be created.

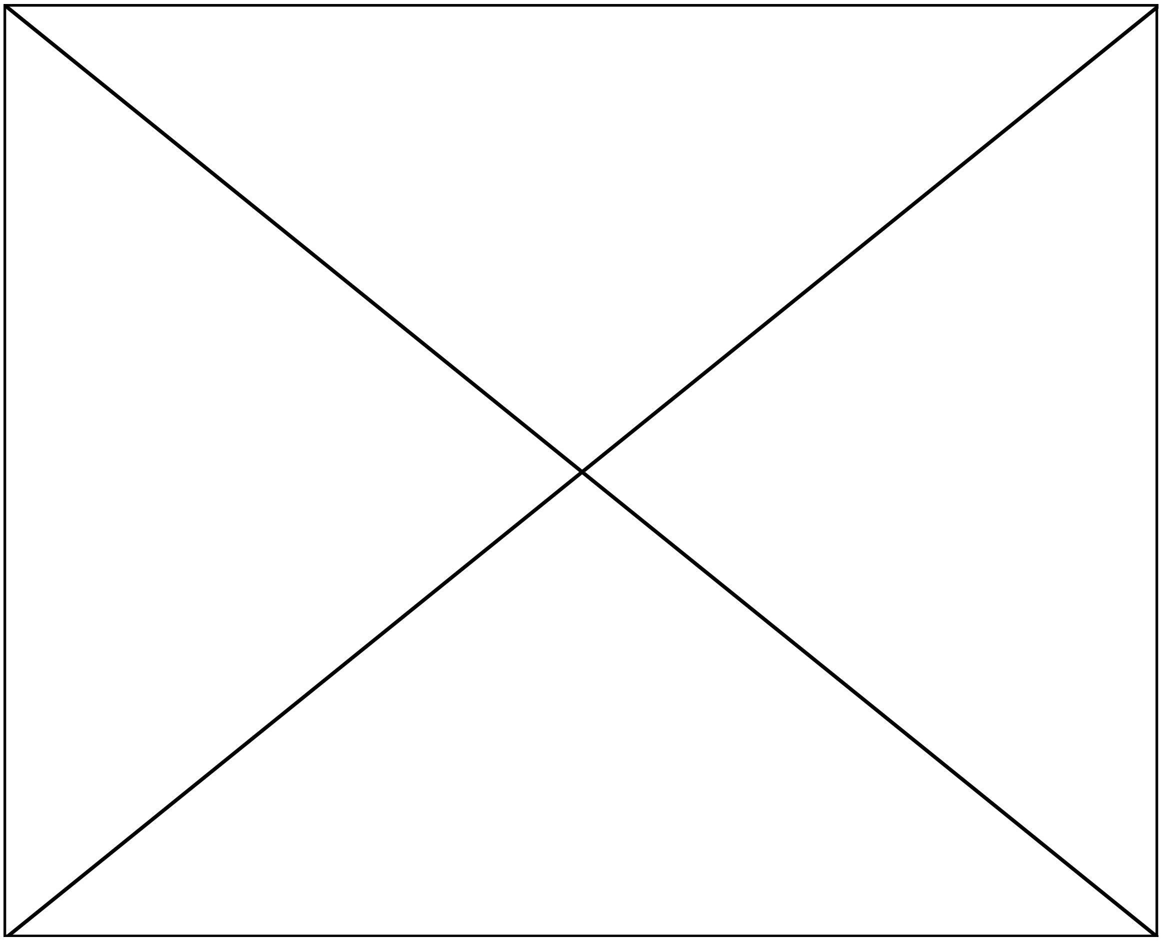

Figure 4 Neural network structure

Factors which occur in exactly half the cases lead to weights of 0.5. Instead of a linear scale, a sigmoidal curve has the advantage that factors which occur around the half-way mark have significance values which are enhanced. This is illustrated in Figure 5.

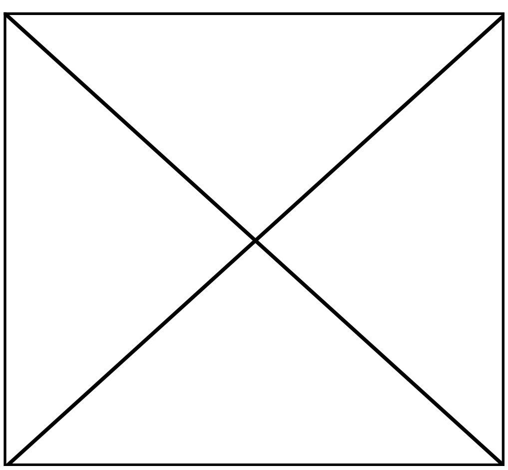

Figure 5 Linear, sigmoid relationships

The weights on links are normalised by the frequency of occurrence of that factor in all cases. Normalisation with respect to the number of factors present in each case was also examined, on the hypothesis that where very large numbers of factors were present, perhaps each should be reduced in importance, but will produce no enhancement to the results achieved without this extra normalisation step, so it is not performed. The significance values after enhancement by the sigmoidal process are then used as the weights. This process enables the network to be built rapidly. Conceptual analysis shows that any statistical relationship between said situational features and objectives is largely spurious. Therefore, there are no direct links between nodes in the situational feature layer and the objectives layer.

Queries are constructed specifying situational features and objectives which act as concept micro-features, as well as cases.

The set of retrieved cases itself contains rankings and gradations according to the strength of activation. Consequently, relevance is not an all or nothing quality, but is relative.

Once the relevant cases have been found by the neural network, the system can then produce a financial plan based on the solutions used in the case(s) which have been found to be the best match to the situational features and objectives of the instance being processed.

8. Operation of the network

The first cycle of processing in the network is special. This produces a baseline of a non-banded or non-discrete valued (continuous) version of vector retrieval as the first set of outputs on the document units. Vector retrieval is a well known method, albeit simplistic, method of retrieving based on statistical affinities between words and documents (Salton, 1971; Bing, 1989). This is useful as an interim result, and is very fast - important in a practical system.

The set of cases produced as an answer to the query can be built up in a number of ways:

- The above mentioned interim set of vector retrieval.
- Those units active when the net has settled in the sense that changes in activations have a low amplitude.
- The case units activated in a short repetitive cycle.
- All those case units above a threshold activation at any time during processing.

Activations of case and factor units are limited to the range between 0 and 1. The ceiling could obviously be any arbitrary value, the floor value of 0 is significant in that an activation of 0 implies that that case or factor unit is not relevant (is excluded from) the query, and is therefore effectively isolated from influencing the rest of the network. Subsequent incoming signals may of course increase its activation and reinstate it.

Activations coming into units are adaptively scaled in a global fashion. This is to guarantee that the network will settle within a reasonably short period, or oscillate in a restrained fashion only.

Global scaling means that the total energy in the network is measured and every unit's activation is reduced pro rata to bring the energy to a pre-specified level. Scaling of activations indirectly affects approximately how many cases are to form part of the answer to the query, as well as how many factors other than those input in either factor layer by way of query are to be considered internally by the network. In other words, scaling affects the scope of the spread of activation. Of course, which cases/factors are active other than those input will be decided interactively by the network.

9. Discussion

The question which must be answered is about the efficacy or sufficiency of the connections between the various units. If one relies on statistical analyses alone, it may be that two factors which any informed person would say are closely related have no direct linkage. Or that one case is known to support another very strongly, yet activation is not propagated alone a direct link between them. This question is really why there are no links between factors within their own layers, nor between cases.

The major reason is to allow the inclusion of new cases at will into the network without degrading the performance. The incorporation of non-statistically derivable information using expertise would cause a significant bottleneck to the inclusion of new cases. The SCALIR (Symbolic and Connectionist Approach to Information Retrieval, Rose & Belew, 1989) adds ‘logical’ links to a network created along connectionist lines. These logical links are those which would be suggested by a domain analysis similar to that carried out for any knowledge system premised on a symbolic approach. So far, the developers of the above system have not reported on whether the use of symbolic links has been successful. All that can be said that the approach is not entirely dissimilar to domain modelling by a knowledge engineer in the usual fashion. This is labour intensive and sacrifices the enormous potential advantages of automatic analyses for a hybridisation with uncertain benefits. Some statistically extractable information could be included in the network, creating connections between factors based on the correlation of their co-occurrence for example. Such information is already available to the network. Since neural networks do not suffer from the problems of for example regression analysis in that all factors must be independent, so there is much less need for pre-processing the data into the network configuration.

In a fast moving sphere such as financial planning, we must be ready to incorporate new cases at any time, and very shortly provide advice which incorporates this new information with the same level of confidence as before. If anything, new cases are more important than old ones.

10. Conclusion

We have shown how a neural network can be integrated into a case-based financial planning system, to discover the case or cases which best match the situational features and objectives of particular instances. The larger system can then produce an appropriate financial plan based on the solutions of these cases, since these cases are exemplary, and pre-selected to reflect reasonableness.

11. References

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