Non-numerical Bankruptcy Forecasting Based on Three Trends Values – Increasing, Constant, Decreasing

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ABSTRACT
There is a broad spectrum of different BM (Bankruptcy Models). However, complex bankruptcies are unique, vaguely known, interdisciplinary and multidimensional. These are the key reasons why sufficiently large sets of examples are not available it is therefore often prohibitively difficult to make forecasts using numerical quantifiers and traditional statistical methods. BMs development suffer from IS (Information Shortage). IS eliminates straightforward application of traditional statistical methods based on information rich environment; that is on the law of large numbers. Artificial intelligence has developed different tools to minimise IS related problems. Trend reasoning is one of them. It is based on the least information intensive quantifiers There are four different trends i.e. qualitative values and their derivatives: plus/increasing; zero/constant; negative/decreasing; any value / any trend. The paper studies BMs represented by models based on EHE (Equationless Heuristics). A bankruptcy example of EHE is – If Selling of Assets is increasing then Satisfaction of Creditors is increasing. Such verbal knowledge items cannot be incorporated into a traditional numerical model. No quantitative quantifiers, e.g. numbers, are used in this paper. The solution of a trend model M(X) is a set S of scenarios where X is the set of n variables quantified by the trends. All possible transitions among the scenarios S are generated. An oriented transitional graph G has as nodes the set of scenarios S and as arcs the transitions T. An oriented G path describes any possible future and past time behaviour of the bankruptcy system under study. The G graph represents the complete list of forecasts based on trends. An eight-dimensional model serves as a case study. Difficult to measure variables are used, e.g. Level of Greed, Political Influence. There are 65 scenarios S and 706 transitions T among them. A priori knowledge of trend reasoning is not required.
INTRODUCTION

Bankruptcies related forecasts represent a broad spectrum of complex tasks difficult to observe (Thomas, 2004). They are often unique and of interdisciplinary nature (e.g. a specific integration of macroeconomics, law, engineering). Bankruptcy related task can be analysed for different aspects (Goodell et al., 2021), see e.g. political situation (Li and Faff, 2019) or Sentiment (Zhao et al., 2022). In other words there is a broad spectrum of different model. Different tools are used to analyse them – statistical analysis, fuzzy or rough sets, genetic algorithms and some other methods of artificial intelligence, see e.g. (Yoon and Hwang, 1995). Soft sciences are often used to develop bankruptcy forecasting models. However, highly nonlinear, vague, partially inconsistent and multidimensional systems are prohibitively difficult to study at the quantitative level. Several types of quantitative simplifications are therefore used, e.g. linearization. The resulting models are oversimplified and therefore inapplicable results are often obtained (Dohnal and Doubravský, 2015).

Formal used tools are: neural networks, genetic algorithms, vague reasoning (fuzzy, qualitative, semi-qualitative, rough, and probabilistic), see e.g. (Punzo, 2003). Numbers and numerical mathematics (e.g. sets of differential equations) are frequently used as well; see e.g. (Acharjya and Rathi, 2021). Some variables are extremely vague and difficult to quantify, e.g. Greed, Sentiment (Zhao et al., 2022). Moreover such problems as rumour spreading, see e.g. (Zhao et al., 2021) put pressure on development, modification and applications of updated algorithms of artificial intelligence.

This paper deals with bankruptcies forecasting under conditions of severe information shortages. Information shortages are likely generators of problems if traditional statistical methods are used. Moreover, the global financial crisis in 2007–2009 is an important reason to take into consideration aging of data records. This makes information / knowledge shortages more serious. Such bankruptcies are often described by non-numerical quantifiers, e.g. words – low, medium, high. However, the transfer of such verbal values into fuzzy sets is very subjective, see e.g. (Chaudhuri and Kajal 2011). Complexities of real-life bankruptcy tasks make any formal description difficult (Wright and Goodwin, 2009). Sets of input information / knowledge items are extremely heterogeneous, see e.g. (Wright and Goodwin, 2009). The following list gives typical items:

- Dominantly Subjective Information
  - Experience
  - Analogy
- Partially subjective information
  - Own observations / measurements
  - Observations which are available on commercial basis
  - Literature sources
  - Verbal descriptions
- Dominantly objective information
  - Mathematical models, e.g. sets of differential equations
    - Without numerical values of parameters
    - With values of constants and parameters
  - Statistical models, e.g. a polynomial function based on the least squares algorithm
    - Original data sets are available
    - No original data sets are available
    - With partial data set availability

Predicting the possibility of bankruptcy is considered as one of the key issues of current economic and financial research. The growing importance of corporate bankruptcy prediction as a research subject has been confirmed in recent years by the appearance of various thorough reviews in the literature with the goal of summarizing the important findings of previously published studies (Matenda et al., 2021). The prediction models can be divided into three main categories:

- Statistical models, see e.g. (Mai et al, 2019)
- Artificial Intelligence, see e.g. (Jardin et al., 2021).
- Combination of statistical, and artificial intelligence techniques see e.g. (Kim et al., 2021).
However, methods of traditional statistical have many restrictive hypotheses, such as linear, normality, and independence hypotheses (Freund et al., 2010). In practice, these hypotheses are difficult to satisfy simultaneously. Hence, the effectiveness and applicability of these models are often very limited (Mai et al., 2019). Recently, methods of artificial intelligence technology have received widespread attention (Mai et al., 2019). Compared with traditional statistical methods, methods of artificial intelligence technology do not have strict restrictive assumptions on the distribution of data; they can also handle large scale data sets and express nonparametric and nonlinear relationships (Wang et al., 2018). Artificial intelligence applications have become an integral part of the financial services industry (Shamima et al., 2022). Common sense is needed to increase the reasoning power to minimise problems related to shortages of observations. In short, computers lack common sense.

1. INFORMATION SHORTAGES

Forecasting and Decision-making related to bankruptcy proceedings are often based on models of unique systems. It means that conventional statistical methods, which are, directly or indirectly, related to the basic law of large numbers, are difficult or impossible to apply. It means that knowledge items of different levels of subjectivity must be taken into consideration to develop the best possible model of a unique task under study. Therefore, many bankruptcy observations are required. However, they are not available.

This is the reason why information non-intensive formal tools are used more and more frequently, see e.g. fuzzy and / or rough sets (Pavláková Docekalová and Kocmanová, 2016; Bocková et al., 2012). Common sense is needed to increase the reasoning power to minimise problems related to shortages of observations. In short, computers lack common sense. Common sense formalization has attracted attention long time ago; see e.g., (Bredeweg and Salles, 2009). Common sense algorithms based just on four values - positive, zero, negative, anything – are studied in this paper. Many bankruptcies related knowledge items are available just as verbal descriptions based on trends: plus/increasing; zero/constant; negative/decreasing. For example:

If Corporate Indebtedness is increasing then Long Run Average Revenue is decreasing more and more rapidly

(1)

All pairwise relations X and Y given in Fig. 1 are trend relations. It means that nothing is quantitatively known. Six examples of quantifier-less pairwise trend relations are given in Fig. 1.

![Figure 1. Examples of trend pair-wise relations](image)

Source: own
For example, the relation 22 indicates that:

- The relation \( Y = f(X) \) is increasing
- There is a linear relationship between \( Y \) and \( X \) \hspace{1cm} (2)
- If \( X = 0 \) then \( Y \) is positive.

The heuristic (1) is represented by the shape No. 21, see Fig. 1.

Moreover the following two types of pairwise proportionalities / relations between variables \( X \) and \( Y \) are considered in this paper:

<table>
<thead>
<tr>
<th>Support</th>
<th>X</th>
<th>Y</th>
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<tbody>
<tr>
<td>Reduce</td>
<td>X</td>
<td>Y</td>
</tr>
</tbody>
</table>

Support: An increase in \( X \) has a supporting effect on \( Y \)
Reduce: An increase in \( X \) has a reducing effect on \( Y \).

An example of complexities and vagueness of subproblems related to bankruptcies studies is the following relationship \( f \) between \( MC \) (macroeconomic conditions), \( CD \) (corporate default) and \( K \) (set of all numerical constants used in \( MC \) and \( CD \)), see e.g. (Xing et al., 2023).

\[ f(MC, CD, K) = 0 \]

The majority of the constants \( K \) are positive and multiplicative. The trivial relation demonstrate a simple way how to eliminate the numerical constants, \( X \) is a variable \( K \).

\[ X = (+) \cdot X = X \]

Therefore trend analysis does not require knowledge numerical constants. It means that their time consuming identification is not required.

The relations (3) are based just on the first derivatives \( dY/dX \). The relations given Fig. 1 require trend quantification of the second derivative \( d^2Y/dX^2 \). It means that the relations (3) are the most vague trend relations.

2. TREND MODELS

There are many different interpretations of trend concepts. The trend concepts as it is used in this paper is based on four values: see e.g. (Bredeweg, 2009), (Vicha, Dohnal, 2008):

<table>
<thead>
<tr>
<th>Positive</th>
<th>Zero</th>
<th>Negative</th>
<th>Any Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

An equationless trend model \( M \) is a set of \( w \) pair-wise relations

\[ M = P_s (X_i, X_j) \hspace{1cm} (5) \]
\[ s = 1, 2, \ldots w \]

Examples / shapes of the relations \( P \) (5) are given in Fig. 1.

An algorithm, which can be used to solve the model (5), is based on pruning of a specially generated tree of combinations. It is not the goal of this paper to describe such algorithm, as it is a purely mathematical combinatorial task, see e.g. (Vicha, Dohnal, 2008).
The model (5) is solved and the set of $n$ dimensional scenarios is obtained $S(n, m)$. There are $m$ scenarios:

$$S(n, m) = (X_1, DX_1, DDX_1), (X_2, DX_2, DDX_2), ..., (X_n, DX_n, DDX_n); \quad j = 1, 2, ..., m$$

where, $DX$ is the first and $DDX$ is the second time trend derivatives. For example, the following three dimensional scenario, $n = 3$ (6)

$$X_1 \quad X_2 \quad X_3$$

$$(+ + +) \quad (+ - 0) \quad (+ - -)$$

indicates that $X_1$ is increasing more and more rapidly, $X_2$ decreases linearly, $X_3$ is decreasing more and more rapidly. All variables are positive – see the first symbol of all three triplets (7).

It is possible to take into consideration higher trend derivative, e.g. the third one $DDDX$. However, studied tasks are ill known and the third trend derivatives $DDDX$ are not available. Another simplification is that the second derivatives are ignored if the studied information items are so poorly known that the second derivatives $DDX$ cannot be evaluated. If the second derivatives are ignored or unknown then the model (5) cannot be described by the shapes given in Figure 1.

Trend proportionalities are therefore introduced, see (3). DTP is a direct trend proportionality and ITP is an indirect trend proportionality:

**DTP**
- If $X$ is increasing then $Y$ is increasing
- If $X$ is decreasing then $Y$ is decreasing
- $DX = DY$

**ITP**
- If $X$ is increasing then $Y$ is decreasing
- If $X$ is decreasing then $Y$ is increasing
- $DX = -DY$

DTP represents the following three shapes, see Fig. 1: 21, 22, and 23. ITP represents 24, 25, and 26.

### 3. TRANSITIONAL GRAPHS

The set of scenarios $S$ (3) is not the only result of a trend modelling. It is possible to generate transitions among the set of scenarios.

![Figure 2. A trend description of a quantitative oscillation](Source: own)
The triplets given in Fig. 2 describe a broad spectrum of different oscillations, e.g. dumped oscillation or irregular oscillations with randomly or deterministically changing frequencies and / or amplitudes.

A complete set of all possible one-dimensional transitions is given in the following table:

**Table 1.** A list of some one-dimensional transitions

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Or</th>
<th>Or</th>
<th>Or</th>
<th>Or</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>+ + +</td>
<td>→</td>
<td>+ + 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>+ + 0</td>
<td>→</td>
<td>+ + +</td>
<td>+ + -</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>+ + -</td>
<td>→</td>
<td>+ + 0</td>
<td>+ 0 -</td>
<td>+ 0 0</td>
</tr>
<tr>
<td>4</td>
<td>+ 0 +</td>
<td>→</td>
<td>+ + +</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>+ 0 0</td>
<td>→</td>
<td>+ + +</td>
<td>+ -</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>+ 0 -</td>
<td>→</td>
<td>+ -</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>+ - +</td>
<td>→</td>
<td>+ 0 +</td>
<td>0 + +</td>
<td>+ 0 0</td>
</tr>
<tr>
<td>8</td>
<td>+ - 0</td>
<td>→</td>
<td>+ + +</td>
<td>+ -</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>+ - -</td>
<td>→</td>
<td>+ 0</td>
<td>+ -</td>
<td></td>
</tr>
</tbody>
</table>

Source: own

For example, the third line of Tab. 1 indicates that it is possible to transfer the triplet (+ + −) into the triplet (+ 0 −). This transition is not the only possible. There are two more possible transitions. Fig. 3 gives a trend description of an oscillation using the one dimensional triplets.

Any quantitative one-dimensional oscillation, see e.g. Fig. 1 and Fig. 2, can be represented by a simple oriented graph, see Fig. 3. There are 8 one-dimensional scenarios, m = 8, n = 1 (6). Any forecasting related to the oscillation Fig. 1 is trivial. For example the scenario (+ + −) is transferred into the scenario (+ 0 −), see Fig. 3.

![Figure 3. Transitional one dimensional graph of an oscillation, see Tab. 1](source: own)

An example of a more complex transitional graph is given in Fig. 4. There are 5 scenarios, m = 5 (6). The transitional graph in Fig. 4 is an example of an unsteady state behaviour of a more complex model (5). If a forecaster accepts the model (5), then the corresponding transitional graph represents all possible trend forecasts and all possible trend histories to choose from; no feasible forecast can be overlooked / ignored. It means that the transitional graph is a generator of trend-based forecasts.
Let us suppose that the scenario No. 4 is under study as a current forecasting root. The following paths are two-steps forecasts:

\[ S_4 \rightarrow S_3 \rightarrow S_5 \]
\[ S_4 \rightarrow S_2 \rightarrow S_3 \] (9)

No other two steps behaviours / forecasts are possible.

The complete description of all past two steps histories is given in (10), if the current root is again the scenario No. 4, see Fig. 4.

\[ S_1 \rightarrow S_2 \rightarrow S_4 \] (10)

The set \( X \) of variables

\[ X = X_1, X_2, ..., X_n = (V \cup G \cup O) \] (11)

\[ V \cap O = \emptyset \]
\[ V \cap G = \emptyset \]
\[ O \cap G = \emptyset \]

\[ V = (V_1, ..., V_v) = (X_1, ..., X_v) \]
\[ G = (G_1, ..., G_t) = (X_{v+1}, ..., X_t) \]
\[ O = (O_1, ..., O_w) = (X_{t+1}, ..., X_n) \]

\[ n = v + w + t, \]

is chosen as relevant. Any forecasting / decision-making will be based on a \( n \)-dimensional model \( M(X) \). A set \( X \) of \( n \) variables is a union of Decision variables \( V \), Goals variables \( G \) and Off-control variables \( O \) (11).

The set \( O \) of variables is not under control of a forecaster / decision maker. If a forecaster is a company’s manager or a government then the set \( O \) is different. This is the reason why future unsteady state behaviours depend heavily on interpretations of the set of variables \( X \) (11).

An example of variables \( X \) presented from the point of view of a company management is:

- **Investments** \( V \)
- **Profit** \( G \)
- **Tax** \( O \)

The variable \( O \) is controlled by a government and not by a company management.
4. CONFRONTATIONS OF MODELS

It is a well-known fact that bankruptcy models’ accuracies are often very low. It is therefore highly desirable to confront results of several models developed by several forecasters / decision makers.

A team of \( r \) forecasters is involved

\[ F_1, F_2, \ldots F_r \] (12)

It is usually not possible to achieve a consensus among a team of \( r \) forecasters. This is the reason why each forecaster has his/her \( n \)-dimensional model:

\[ M(n)_1, M(n)_2, \ldots M(n)_r \] (13)

The models (13) are solved and sets of trend \( n \)-dimensional scenarios \( S \) are obtained:

\[ S(n)_1, S(n)_2, \ldots S(n)_r \] (14)

The Core and Envelope sets of scenarios (14) are, see e.g. (Dohnal and Doubravský, 2015):

\[ S_{\text{COR}}(n) = S(n)_1 \cap S(n)_2, \ldots \cap S(n)_r \] (15)

\[ S_{\text{ENV}}(n) = S(n)_1 \cup S(n)_2, \ldots \cup S(n)_r \]

The set \( S_{\text{COR}} \) eliminates all atypical scenarios and \( S_{\text{ENV}} \) covers all possible scenarios generated by all decision makers. It is obvious that \( S_{\text{ENV}}(n) \) is a superset of \( S_{\text{COR}}(n) \):

\[ S_{\text{ENV}}(n) \supseteq S_{\text{COR}}(n) \] (16)

5. CASE STUDY

Any trend analysis is a combinatorial problem. A tutorial example of a trend model of a bankruptcy is given in (Doubravsky, Dohnal, 2018). There is a strong correlation between the number of scenarios and the number of variables. If a number of scenarios is more than 50 then the corresponding transitional graph is very complex. Several hundreds scenarios is not an exception. This is the reason why just nine variables are used (17). Moreover, there is no need to define the variables precisely. One has to keep in mind that just trend quantifications are required. E.g. if GRD (Greed) variable is increasing then it is irrelevant that a description of specific set of activities is not given.

Variables that have a significant impact on the bankruptcy forecasting have been carefully selected to reflect heterogenous nature of the tasks under study. A discussions with a small team of experts and PhD students was organised.

\[ SEL \] Selling of Assets
\[ ENV \] Ensure Justice
\[ GRD \] Level of Greed
\[ TAX \] Tax Burden
\[ SAT \] Satisfaction of Creditors
\[ SOL \] Solution of Debtors Assets
\[ POL \] Political Influence
\[ BUL \] Bullying of Creditors
\[ INF \] Inflation

The very nature of the variables (17) indicates that they are difficult to quantify, see e.g. Level of Greed.

Let us suppose that there are two experts / forecasters, \( r = 2 \) (12):

\[ E_1 \text{ and } E_2 \] (18)

The first expert \( E_1 \) developed the following model:
There are 65 scenarios; $m = 65 \,(6, \,19)$,

<table>
<thead>
<tr>
<th>#</th>
<th>SELENJ</th>
<th>GRD</th>
<th>TAX</th>
<th>SAT</th>
<th>SOL</th>
<th>POL</th>
<th>INF</th>
<th>see (17)</th>
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<td>+0</td>
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</table>

There are 706 possible transitions among 65 scenarios (20). The transitional graph is very complex, see Figure 5.

**Figure 5.** Transitional graph based on the set of 65 scenarios (19)

Source: own
The second expert $E_2$ (18) modified the model of the first expert. The following relation:

$$6 \ 25 \ \text{ENJ BUL}$$

was used.

Therefore the model of the second expert is:

1. $\text{DTPSENJ}$
2. $\text{25 SELGRD}$
3. $\text{21 SELSAT}$
4. $\text{24 SELSOL}$
5. $\text{23 ENJTAX}$
6. $\text{25 ENJBUL}$
7. $\text{DTPTAX POL}$
8. $\text{24 SATBUL}$
9. $\text{DTPPOLINF}$

There are 29 scenarios (21).

<table>
<thead>
<tr>
<th>No.</th>
<th>SEL</th>
<th>ENJ</th>
<th>TAX</th>
<th>SAT</th>
<th>SOL</th>
<th>POL</th>
<th>BUL</th>
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\[ (21) \]

**Figure 6.** Transitional graph based on the set of 29 scenarios (22)

Source: own
Both models (19, 21) are heavily subjective. An elimination of atypical scenarios is therefore desirable. An intersection (see the Core (15)) of the sets of scenarios (20, 22) removes such potentially atypical scenarios. The intersection has 27 scenarios, see (23). It means that just two scenarios removed from the set (22).

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Figure 7. Transitional graph based on the set of 29 scenarios (23)

Source: own
Any forecasting is heavily predetermined by interpretations of variables (11). The choice of the sets $V$, $O$, $G$, is of crucial importance and is based on the current point of view.

Let us suppose that the following interpretations of variables are done from the point of view of a government:

- **SEL** $V$ Selling of Assets
- **ENJ** $V$ Ensure Justice
- **GRD** $V$ Level of Greed
- **TAX** $O$ Tax
- **SATG** $G$ Satisfaction of the Creditors
- **SOL** $G$ Solution of Debtor’s Assets
- **POL** $O$ Political Influence
- **BUL** $V$ Bullying of Creditors
- **INF** $O$ Inflation

(24)

It means that, see (11):

$O = \{\text{POL, INF, TAX}\}$

$G = \{\text{SAT, SOL}\}$

$V = \{\text{SEL, ENJ, GRD, BUL}\}$

A simple common sense analysis indicates that there are two different points of views and forecasts:

- Debtor’s
- Creditor’s

$G$ variables are objective functions, using the terminology of multi objective optimisation. However, we are not looking for a compromise. Therefore, two opposing views are studied; see Fig. 8 and Fig. 9.

**Figure 8.** Debtor’s view – where $t$ represents a variable time

Source: own

**Figure 9.** Creditor’s view - where $t$ represents a variable time

Source: own
The worst trend description of the Debtor´s view is:

SAT  Increase more and more rapidly  \( DSAT = + \)  \( DDSAT = + \)  (25)
SOL  Decreasing more and more slowly  \( DSOL = - \)  \( DDSOL = + \)

The worst trend description of the Creditor´s view:

SAT  Decreasing more and more slowly  \( DSAT = - \)  \( DDSAT = + \)  (26)
SOL  Increase more and more rapidly  \( DSOL = + \)  \( DDSOL = + \)

CONCLUSION

A broad spectrum of research activities in artificial intelligence has generated many different methods, algorithms and methodologies, which can be potentially used for forecasting and related areas.

A forecast user requires transparent and easy to understand explanations why and how different algorithms generate some forecasts. If formal tools are mathematically too demanding then it is very difficult to introduce them into the broad forecasting community. The trend transitional graphs can be explained using just elementary concepts of derivatives.

There are three main advantages of the trend based forecasting:

- No numerical values of constants and parameters are needed
- It is possible to develop multidimensional models based on verbal knowledge items, e.g. heuristics
- The set of trend scenarios is a superset of all meaningful scenarios, i.e. forecasts.

No reasonable forecast can be missed if the analysis is based on a good trend model.

The aim of this paper is to ensure a certain procedure for relief from debts so that both parties are satisfied. The paper explores a set of trend heuristics, i.e. a trend model.

Developments of the trend models do not require knowledge of complicated theories of artificial intelligence. These methods are used as black boxes. An important advantage of the trend forecasts is that anybody can develop a model based on elementary knowledge of mathematics. The authors are ready to make the relevant calculations of a model is delivered.

It is very probable that developments of relevant formal tools of artificial intelligence will have important consequences. Naïve physics and consequently algorithms based on common sense reasoning will be used in Bankruptcy models and related tasks more and more extensively.

REFERENCES


