Analysis of Financial Data Anomaly Based on Data Mining Technology

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Abstract
Through the anomaly analysis of financial data, this paper research on the method of anomaly analysis in association data mining. Through the high dimensional multivariate statistical analysis of the mapping relationship between financial data, the author extracts the relevant dimension information which reflects the abnormal characteristics of financial data, and establishes the discriminated statistics and inspection standards. The empirical analysis results show that using the method of property Business analysis of abnormal data, can effectively extract the abnormal characteristics of financial data to the information flow, better accuracy of abnormal financial data mining, strong anti-interference ability, intelligence and Real-time Anomaly Analysis of financial data is good.

Key words: Data mining, financial data, statistical audit, correlation features

1. INTRODUCTION

With the development of large data information processing technology, it provides strong data support for the statistical departments and financial audit departments to use large data information processing methods for financial data processing and analysis. The financial data includes bank journal data, financial expenditure data, and financial income data etc. The data mining and information feature extraction technology are used to analyze the anomaly of financial data. The attribute features reflecting abnormal information of financial data are mined to realize scientific analysis of financial data. The study of abnormal analysis method of financial data has important application value in economic crime investigation and audit investigation.

There are many factors affecting the abnormalities of financial data. The distribution features of abnormal attributes have big randomness, with the features of time-varying and autocorrelation coupling. It is difficult to analyze the anomaly of financial data. The construction of abnormal features mining model for financial data is a kind of abnormal features mining and data prediction problem for a group of economic sample sequences. In the traditional method, the anomaly analysis method for financial data mainly includes supporting vector machine method, decision tree analysis method, and statistical feature analysis and autocorrelation feature mining method. The abnormal attribute mining of financial data is achieved with the above method decomposing the economic analytic model of financial data as the statistics including multi-linear components, so as to realize the feature reconstitution and multivariate linear equation of financial data by the statistics information processing of financial data and empirical data analysis method, thus to test your financial data anomaly analysis, and achieve some research result.

In this paper, a statistical feature analysis and abnormal behavior mining method of financial data based on CART decision tree data mining model is presented in literature. Semantic similarity statistical analysis method is combined to realize entity identification and attribute correlation analysis of financial data to extract information feature mutually for data flow and anomaly mining of financial data, but this method cannot effectively realize the decoupling of financial data in the analysis. The singularity in data mining process is bigger and the cost of parallel computing is larger. Literature proposes a method for analyzing the abnormal financial data based on supporting vector machine and analytical method of PCA main component. Firstly, redundant information of financial data is filtered and carried out with reduplication processing to reduce computational overhead of financial data analysis, extract spectral features of financial data flow, combining high order spectral analysis for financial data abnormal feature extraction, to achieve nonlinear time series analysis of financial data and significant difference analysis of abnormal data, but the immunity of this method is not good in performing the anomaly analysis of financial data, and accuracy of anomaly feature mining is not very high.

In order to solve the above problems, this paper proposes a method of financial data anomaly analysis based on correlation data feature mining technology. Firstly, the phase space reconstitution method is used to carry out high dimensional feature expansion of financial data. The principal component analysis method is used for auto-correlation feature matching of financial data, combining with the alternative data method for randomization processing of financial data, and then feature compression method is used for non-correlation redundancy processing. High-dimensional multivariate statistical analysis is combined for correlation mapping of financial data, to extract the correlation data reflecting the abnormal features of financial data, construct the
discriminant statistics and test criteria. Financial data anomaly feature mining is carried out according to the significant difference of discriminant statistics to achieve abnormal financial data analysis. Finally, the empirical data analysis and simulation experiments are carried out. The method in this paper is used to realize the abnormal analysis of financial data, which is shown, to draw the conclusion of validity.

2. INFORMATION FLOW RECONSTITUTION AND PREPROCESSING OF FINANCIAL DATA

2.1. Financial data flow reconstitution

In order to realize the anomaly analysis of financial data, information flow model of financial data needs to be constructed to extract the abnormal characteristics of financial data, analyzing the change and increasing situation of financial data through the data mining technology, to provide the reference index for financial statistics and auditing department. The paper analyzes the statistical characteristics of financial data through constructing a mining model for financial data and journal trend effectively and synthesizing financial data feature distribution, adopting certain mathematical model construction method to construct information flow model of sampling financial data, combining economic sequence analysis method to make financial data flow reconstitution and feature reorganization.

The financial data is a set of nonlinear economic sequences. The nonlinear economic sequence analysis method can be used to mine the abnormal characteristics of financial data. Through statistics and sampling of apriori information of financial department, inversion economic sequence of univariate financial data can be constructed as \( \{x_n\} \). High-dimensional phase space reconstitution technology is used for financial data correlation feature reorganization. The abnormal characteristics of financial data is analyzed in the phase space.

The information flow model of financial data high-dimensional characteristics is \( \{x_n\}_{i=1}^{N} \). Optimal correlation decomposition of the data is done. The phase space vector model of financial data obtained in the reconstituted dimension space is described as:

\[
L = \begin{bmatrix}
    x_1^T \\
    x_2^T \\
    \vdots \\
    x_N^T
\end{bmatrix}
= \begin{bmatrix}
    x_1 & x_{1+r} & \cdots & x_{1+(m-1)r} \\
    x_2 & x_{2+r} & \cdots & x_{2+(m-1)r} \\
    \vdots & \vdots & \ddots & \vdots \\
    x_{N-r} & x_{N-r+r} & \cdots & x_{N-r+(m-1)r}
\end{bmatrix}
\]

(1)

In the formula, the embedding dimension of financial data in the phase space is \( m \). The sampling time delay of financial data is \( \tau \). In the \( m \) dimension space of reconstituted data map, the attribute characteristics reflecting financial data category is extracted. The test and statistic model of financial data \( L \) is constructed to generate a Gaussian time series \( y(n) \) and a discriminant statistical model of financial data is constructed to generate the corresponding alternative sequence:

\[
x_n = \phi_0 + \sum_{i=1}^{3} \phi_i x_{n-i} + \sum_{j=0}^{2} \theta_j \eta_{n-j}
\]

(2)

In the equation, \( \{\eta_i\} \) is financial data redundancy interference item with mean value of 0, and variance of \( \sigma^2 \), \( \phi_0, \phi_1, \phi_2, \cdots, \phi_3 \) is known as randomization coefficient, \( \theta_0, \theta_1, \cdots, \theta_2 \) is known as time window. The singular value decomposition method is used to obtain the inversion irreversible value of financial data anomaly feature mining. The singular value decomposition process is \( L = U \ast S \ast C \), \( U \) and \( C \) is a phase randomized matrix, and \( C = (c_1, c_2, \cdots, c_r) \)

(3)

Fourier conversion is carried out for the statistical series of original financial data. Sigma test criterion is used to obtain the third order autocorrelation value of financial data to get the generalized inverse positive solution of financial data distributed in the phase space. Here, \( S \) is the singular value of \( L \). The main component vector of financial data redundancy information is:

\[
S = diag(\sigma_1, \sigma_2, \cdots, \sigma_r), \ \sigma_1 \geq \sigma_2 \geq \cdots \geq \sigma_r \geq 0
\]

(4)

For any orthogonal matrix, in the linear subspace, phase space reconstitution track matrix \( L \) and self-organizing map functional is used to get the phase space control matrix of \( N \times m \) dimensions through balance point control;
\[
X = \begin{bmatrix}
    x_1 \\
    x_2 \\
    \vdots \\
    x_i
\end{bmatrix} = \begin{bmatrix}
    a_1^T c_1 & a_1^T c_2 & \cdots & a_1^T c_n \\
    a_2^T c_1 & a_2^T c_2 & \cdots & a_2^T c_n \\
    \vdots & \vdots & \ddots & \vdots \\
    a_i^T c_1 & a_i^T c_2 & \cdots & a_i^T c_n
\end{bmatrix}
\]

In this paper, \( J^{(N)} \) is obtained through singular value decomposition of the ith eigenvector \( J^{(N)} \), combining the non-linear anomaly feature mining method for the maximum Lyapunove index functional of financial data. Set up a separation coefficient \( J^{(m)} \) for the separation processing of redundant information of financial data according to the number of training samples of financial data and abundance of redundant data. Blind source separation technology is adopted to get the blind source separation covariance matrix \( C \) of financial data:

\[
C = \frac{1}{N} \left[ X - \overline{X}_j \right] \left[ X - \overline{X}_j \right]^T
\]

In the equation:

\[
l = [1,1,\cdots]_{i=N}^{i=N}
\]

\[
\overline{X}_j = \frac{1}{N} \sum_{i=1}^{N} x_i
\]

\[
X = [X_1, X_2, \cdots, X_n]
\]

Remove the dimension of original financial data to get the slack variable of financial data in the phase space:

\[
\delta x_{i+1} = J^{(m)} \delta x_i
\]

In the equation \( \delta x_i = x_i - x_i \), \( x_i \) is the vector quantization information of the original data sample sequence in phase space, and the corresponding m principal component feature subset is \( x_j = k^m \). So let \( x_{i+1} = \mu x_n(1-x_n) \) be the state information parameter of abnormal distribution of financial data. When the detection statistic meets \( \delta x_{i+1} = x_{j+1} - x_{i+1} \), autoregression ARMA estimation is carried out through financial economic sample sequence of the original statistics [8] to get \( \delta x_{i} \) and \( \delta x_{i+1} \). And when the number of principal components satisfies the constraint condition \( V - \sum_{i}^{i=N} S_i \), cumulative variance of financial data is calculated in the reconstituted phase space, and the Euler distance of financial data flow distribution track in high-dimensional phase space meets:

\[
\| x_j - x_i \| \leq \varepsilon
\]

In the formula, \( \varepsilon \) is a small positive number, thus the relevance mapping vector \( X_i \) of financial data is determined, thus forming a ontology model writing matrix form of financial data parallel mining:

\[
B_x = \left( \delta x_1, \delta x_2, \cdots, \delta x_1 \right)
\]

Through the above phase processing, phase space reconstitution method is used to carry out high dimensional feature expansion of financial data, providing the original data input basis for the abnormal analysis of financial data.

2.2. Autocorrelation feature matching of financial data

Based on high-dimensional feature expansion of financial data by using phase space reconstitution method, the principal component analysis method is used for auto-correlation feature matching of financial data, to improve the accuracy for mining of financial data anomaly. Time-frequency analysis method is used to obtain the correlation dimension of financial data as:

\[
x(t) = \text{Re}\{a_n(t)e^{-j2\pi f_k\tau_n(t)}(t - \tau_n(t))e^{-j2\pi f_k(t)}\}
\]

In the formula, on the time scale of information flow distribution of financial data, multiple wavelets are decomposed to get the transient disturbance of financial data as:

\[
c(t, \tau) = \sum_{n} a_n(t)e^{-j2\pi f_k\tau_n(t)}\delta(t - \tau_n(t))
\]

In the equation above, \( a_n(t) \) is the inversion integral function of abnormal feature performed on the nth
phase space distribution trajectory. \( \tau_{n(t)} \) is the time delay of financial empirical sampling. \( f_r \) is the sampling frequency of main feature quantity of financial data, and \( s_i(t) \) is the transitional information of simple component.

The grid segmentation method is used for transient state disturbance optimization of financial data, and the optimal correlation distribution function of financial data is obtained as follows:

\[
h(t) = \sum_{i=1}^{P} a_i p(t - \tau_i)
\]

(15)

In the equation, \( a_i \) and \( \tau_i \) are the similarity coefficient and disturbance amplitude respectively. The relevance mapping of financial data is carried out in the reconstituted high-dimensional feature space of financial data, and the attribute characteristics reflecting financial data category are extracted, to get the autocorrelation feature distribution function of financial data as:

\[
\begin{align*}
y(t) &= x(t - t_0) \Rightarrow W_i(t, v) = W_i(t - t_0, v) \\
y(t) &= x(t)e^{i2\pi t} \Rightarrow W_i(t, v) = W_i(t, v - v_0)
\end{align*}
\]

(16)

Through the time-frequency scaling, spectral analysis technology is used for the abnormal feature clustering process of financial data. The data clustering center for the construction of financial data abnormal feature mining is described as:

\[
y(t) = \sqrt{k} x(kt), k > 0
\]

(17)

\[
W_i(t, v) = W_i(kt, v / k)
\]

(18)

Here, \( k \) refers to the disturbance amplitude of data clustering, \( v \) is expressed as the sampling spectrum value of financial data, \( W_i \) is the time window function. Set the amplitude of financial data anomaly feature mining information flow as \( A \). Main feature quantity \( N_i(x) \) of optimal correlation data of financial data is obtained. The alternative data analysis method is used to get the information classification error of financial data:

\[
W_i(t, v) = \int_{-\infty}^{\infty} x(t + \tau / 2)x^*(t - \tau / 2)e^{-i2\pi t} d\tau
\]

(19)

In the finite domain, the frequency domain distribution of abnormal characteristics of financial data is expressed as:

\[
W_i(t, v) = \int_{-\infty}^{\infty} X(v + \xi / 2)X^*(v - \xi / 2)e^{i2\pi \xi} d\xi
\]

(20)

In the above equation, \( \xi \) is the attenuation coefficient in the clustering process of financial data abnormal features, and \( X \) is the bifurcation distance of financial data classification vector. \( X^* \) refers to looking for the conjugate of the financial data. Hyperbolic frequency modulation is carried out for financial data anomaly detection system. According to autocorrelation \( r \) feature matching technique, the matching result of abnormal feature is:

\[
p(Q_i) = a_k \frac{1}{\sqrt{2\pi}\sigma} \exp \left\{ -\frac{(Q_i - Q)^2}{2\sigma^2} \right\}
\]

(21)

Here, \( a_k \) is recognition coefficient of financial data attribute. If \( a_k = 0 \), it means the \( k \)th abnormal data clustering center tends to zero. If \( a_k = 1 \), it means there is a disturbance in the clustering space, it indicates that there is abnormal data.

3. REALIZATION OF FINANCIAL DATA ABNORMAL MINING

3.1 Randomization and de-redundancy processing of financial data

Based on the information flow reconstitution and autocorrelation feature matching of financial data performed above for abnormal feature mining, this paper presents a method to analyze the abnormal financial data based on the correlation data feature mining technology. Alternative data method is used for the randomization of financial data processing. Alternative data method is from the modern statistics Bootstrap theory, and the realization process is described as:

1. Phase-randomize the original financial data to generate a set of Gaussian economic sequences \( y(n) \) to obtain a linearly related Gaussian process;
(2) Take the rank of the original financial data \( x(n) \) as the association rule mapping vector set, for the financial data association rule mapping
\[ r_n = y(x_n) = y_{\text{rank}(x_n)}, \quad n = 1, 2, \ldots, N \]  

(22)

In the association rule mapping system, the quaternion group of financial data attribute classification is constructed;

(3) \( (r(n))_{n=1}^{N} \) is made Fourier transformation, and optimal matching of financial data is carried out to get a new sequence \( y'(n) \), and the association rules and autoregressive eigenvectors are the same;

(4) According to the rank of \( y'(n) \), financial data is rearranged to achieve the randomization processing of financial data and generate alternative sequences.

The attribute characteristics reflecting abnormal information of financial data are extracted, and elimination of redundancy is made for the substitute data \( x(k) \). The redundant vector of the financial data is:
\[
W_s(t, v) = \int_{-\infty}^{\infty} W_s(t-x, v)W_s(x, v)ds
\]

(23)

In the equation, \( t \) is data sampling time, \( s \) is correlation coupling coefficient of financial data. In the data clustering center, the self-adaption weighting \( W_s = (\alpha_s^{(e)}, 0) \) of financial data classification is carried out non-correlation redundancy removal process by feature compression method. K-L transformation is used to obtain characteristic compression results:
\[
\left[\int_{-\infty}^{\infty} x(t)y'(t)dt\right]^2 = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} W_s(t, v)W_s^*(t, v)dtdv
\]

(24)

Set the error of abnormal information mining of financial data as \( \bar{p} = \sum_{p=0}^{N} p \theta_p(x) \). The nonlinear abnormal feature mining is used to get the non-correlation redundancy blind source separation results of the financial data as:
\[
f_j(t) = \frac{\int_{-\infty}^{\infty} vW_{s,j}(t, v)dv}{\int_{-\infty}^{\infty} W_s(t, v)dv}
\]

(25)

In the equation, \( x_a \) is the number of main components reflecting abnormal information in the financial data information flow.

3.2. Analysis of abnormal characteristics of financial data

In the nonlinear economic sequence of financial data, high-dimensional multivariate statistical analysis method is used to map the financial data. Assume that the financial data is generated by the linearly related nonlinear economic sequence, and the following ARMA model is used:
\[
x_n = \beta_0 + \sum_{i=1}^{M}\beta_i x_{n-i} + \sum_{j=0}^{M}\beta_j \eta_{n-j}
\]

(26)

In the equation, \( \alpha_0 \) is the sampling amplitude of initial financial data, \( x_{n-i} \) is the financial data scalar economic sequence with the same mean, variance, \( b_j \) is the oscillation amplitude of financial data. Third-order autocorrelation statistic is used as the inspection statistical data of financial data abnormal analysis:
\[
C_{x,3} = \frac{\langle (x_n - \bar{x})(x_{n-d} - \bar{x})(x_{n-2d} - \bar{x}) \rangle}{\langle (x_n - \bar{x})^3 \rangle}
\]

(27)

In the equation, \( x_n \) refers to non-linear economic sequence of financial data, \( d \) refers to the time interval for sampling financial data, \( D = 2d \), \( \bar{x} \) represents the mean, \( \langle x(n) \rangle \) represents taking the mean of the financial data sample \( x(n) \):
\[
\langle x(n) \rangle = \frac{1}{N} \sum_{n=1}^{N} x(n)
\]

(28)

The trajectory of non-linear economic sequence and vector feature economic sequence of financial data in the high-dimensional phase space is \( \{x(t_0 + i\Delta t)\}, i = 0, 1, \ldots, N-1 \). Decision tree model is used for the anomaly
of financial data. The basic idea is to measure the time-varying characteristics of economic data and randomness characteristics $X$ and $X_{n+\tau}$. Through the linear correlation processing, the average mutual information $C(\tau)$ of financial data is defined as:

$$C(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_{-\infty}^{\infty} x(t)x(t+\tau)d\tau$$  \hspace{1cm} (29)$$

In the equation, $\tau$ is the time delay of financial data in the reconstituted phase space, representing the correlation degree of financial data change at the time of $t$ and $t+\tau$. The abnormal behavior trend and abnormal feature of financial data are mined based on the correlation degree to get the correlation dimension information in vector space of financial data economic sequence as:

$$I(\tau) = -\sum p_i(\tau)\ln \frac{p_i(\tau)}{p_i}$$  \hspace{1cm} (30)$$

A point in the economic sequence phase space of reconstituted financial data is expressed as $X^*$, and the nearest neighbor point in the set of stochastic phases of financial data is expressed as $X_{n(m)}$, thus the economic sequence exported by financial data anomaly feature mining is:

$$X(n) = \{x(n), x(n+\tau), \cdots, x(n+(m-1)\tau)\}$$  \hspace{1cm} (31)$$

Finally, Sigma test method is used to construct the test criterion of abnormal feature mining of financial data. According to the significant difference of discriminant statistic, the accuracy of abnormal feature mining of financial data is tested. The test criteria is:

$$p(Q_i) = \frac{1}{\sqrt{2\pi}\sigma} \exp \left[ -\frac{(Q_i - \langle Q_i \rangle)^2}{2\sigma^2} \right]$$

$$\int_{-\infty}^{\infty} p(Q_i)dQ_i = 1$$  \hspace{1cm} (32)$$

In the equation, $p(Q_i)$ curve is shown as figure 1.

According to Figure 1, financial data abnormal feature mining distribution meets the standard normal distribution, and if the difference between $Q_0$ and $\langle Q_i \rangle$ exceeds a certain threshold $c$, making:

$$p\left(Q_0 - \langle Q_i \rangle > c\right) \leq 0.05$$  \hspace{1cm} (34)$$

At this point the confidence of financial data mining is 95%, because the normal distribution is symmetrical on both sides of $\langle Q_i \rangle$, there should be:
0.025 = \int_{-\infty}^{\infty} p(Q_i) dQ_i = 1 - \int_{-\infty}^{\infty} p(Q_i) dQ_i \quad (35)

In the equation, \( z_2 = -z_i \), when \( S \geq 2.00 \), the abnormal distribution of financial data is not established with 95% probability, accepting the original hypothesis, the financial data anomaly mining results meet the convergence conditions.

4. SIMULATION EXPERIMENT AND RESULT ANALYSIS

In order to test the performance of this method in the realization of financial data anomaly analysis, simulation experiments and empirical data analysis are carried out. The hardware environment of simulation experiment is PC. The configuration parameters are CPU 3.0 G, Core (TM) CPU T6600, 12G internal storage. The empirical data analysis software includes Excel 2007 and SPSS19.0. The related parameters of financial data test statistics are: \( Q = 200 \), \( c_1 = 30 \), \( c_2 = 10 \), \( c_r = 2 \), \( \mu_1 = \mu_2 = 0.01 \), \( \rho_1 = \rho_2 = 0.01 \), \( \delta = 0.8 \). The financial data is from a large group, and the statistical time is from January to April 2017. The similarity correlation coefficient of financial data is \( \mu = 12 \). The abnormal feature sampling rate of financial data is \( f_s = 10 \times f_0 \text{Hz} = 10 \text{KHz} \), and the frequency band of data distribution is 4 ~ 25 KHz. According to the F test and correlation analysis of financial data carried out with Hausman test, the correlation coefficient is shown in Table 1.

<table>
<thead>
<tr>
<th>Correlation coefficient</th>
<th>( x_1 )</th>
<th>( x_2 )</th>
<th>( x_3 )</th>
<th>( x_4 )</th>
<th>( x_5 )</th>
<th>( x_6 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_1 )</td>
<td>1</td>
<td>0.543</td>
<td>0.454</td>
<td>0.454</td>
<td>0.235</td>
<td>0.543</td>
</tr>
<tr>
<td>( x_2 )</td>
<td>0.345</td>
<td>1</td>
<td>0.454</td>
<td>0.456</td>
<td>0.365</td>
<td>0.432</td>
</tr>
<tr>
<td>( x_3 )</td>
<td>0.454</td>
<td>0.435</td>
<td>1</td>
<td>0.654</td>
<td>0.432</td>
<td>0.212</td>
</tr>
<tr>
<td>( x_4 )</td>
<td>0.543</td>
<td>0.654</td>
<td>0.465</td>
<td>1</td>
<td>0.638</td>
<td>0.345</td>
</tr>
<tr>
<td>( x_5 )</td>
<td>0.875</td>
<td>0.432</td>
<td>0.543</td>
<td>0.854</td>
<td>1</td>
<td>0.512</td>
</tr>
<tr>
<td>( x_6 )</td>
<td>0.754</td>
<td>0.345</td>
<td>0.323</td>
<td>0.843</td>
<td>0.654</td>
<td>1</td>
</tr>
</tbody>
</table>

According to the priori statistical results of financial data samples, the time-domain waveforms of the samples of 4 groups of financial data are shown in Fig.2

![Figure 2. Financial data samples](image)

The abnormal feature mining is carried out for the sampled financial data. The correlation dimension feature of financial data is mined to get the abnormal feature mining results of financial data, as shown in Figure 3.
After analyzing the results of Figure 3, it shows that the method in this paper for the associated information mining of financial data anomaly characteristics has obvious beam directivity, indicating that the anti-interference ability is obvious. In order to compare performance, the method in this paper and traditional method are used to analyze the accuracy of financial data anomaly feature mining. The results are shown in Figure 4. The analysis shows that the method in this paper for financial data anomaly mining is more accurate. It improves the right mining ability for the abnormal data mining.

5. CONCLUSION

In this paper, financial data anomaly analysis method is studied. A method of financial data anomaly analysis based on correlation data feature mining technology is proposed. The phase space reconstitution method is used to carry out high dimensional feature. The principal component analysis method is used for correlated features matching, combined with alternative data method for randomization of financial data. Feature compression method is used for non-correlation redundancy removal processing. High-dimensional multivariate statistical analysis method is used for correlation mapping of financial data. The correlation dimension information reflecting the financial data abnormal feature is extracted to construct discrimination statistic and test criterion. The abnormal feature of financial data is mined according to the significant difference of discrimination statistic to realize anomaly analysis of financial data. The results show that the accuracy of financial data anomaly mining is better than that of financial data, and the accuracy of financial data is analyzed. The results show that the accuracy of financial data anomaly mining with this method is better. It has good application value in the financial audit and economic investigation and other fields.

References