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Trust based stock recommendation system - a social network analysis approach

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Abstract

We propose a novel system to recommend the leading investment option in stocks utilizing a methodology based on the transactions of trusted mutual funds and their corresponding stock holding portfolio. The network formed by the stock holding portfolio is the mutual funds are analysed by the tools of social network analysis. The analysis of the method using the Indian mutual funds data qualifying CRISIL-1 rating shows that it can effectively be used as a reliable portfolio recommendation system for non-professional investors looking for stock investment guidance and reveals the similarity between investment pattern of various Indian mutual funds.

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1. Introduction

Stock market investment is an area that has been gaining long-term traction and attention by financial institutions, individuals and multiple research communities. Judging a favourable investment decision on the plethora of available stocks in the market is a tiresome and challenging task. There is considerable amount of uncertainty about the nature of returns and hence poses difficulty in the decision-making process associated with selection of securities. There is a need to strike the right balance between expected return (maximize) and associated risk (minimize)¹. There are multiple analytical methodologies employed for decision making in stock exchanges, which could be broadly categorised into two groups viz. Technical analysis and Fundamental analysis². Fuzzy expert systems as well as artificial neural networks were employed to analyse the stock market and measure the attractiveness measure of the participating companies². Luo et al.³ have designed a decision support system for projecting buying or selling decisions utilising principles of fundamental analysis together with considering technical indicators. Primarily these systems were developed for novice investors to aid in making subjective judgements regarding stock selection as per their individual

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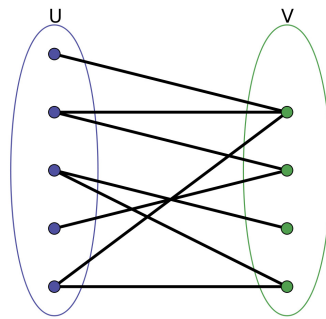


Fig. 1. Bi-Partite Graph representation mutual fund portfolio network

requirement. The opinion of an expert is derived out of his experience gained by analysing stock features over a period of time. The two key components of credibility of a recommendation identified the majority of researchers are trustworthiness and expertise in order to counter the uncertainty a fuzzy expert system was proposed by Fasanghari et al.⁴. Another way of getting insight into what investors and traders thinking about a particular stock is carry out a *sentiment analysis* of Twitter data (tweets) of investors. Investors also connect with one another to discuss, trade, invest, learn and share knowledge across the network. The analysis of the investors network thus formed could provide insight into the wisdom of the crowds to help one make smarter investment decisions. However in such networks the trust between individuals can not be fully depended and the relationships could be falsely built. If one knows that his tweets are followed then he can put fake tweets and false information to influence our investment decision, which is considered as the main problem of social network analysis. Discovering trust in relationships among entities of a social network which leads to a trust-based social network is a promising solution to this problem. This can be further improved by incorporating an expert opinion as the trusted expert advice will lead to better results. Attempts have been made to develop social network of financial experts based on their publicly listed portfolios for further analysis to recommend an appropriate portfolio to a novice investor⁵. However classifying the type of knowledge that different experts have is a challenging problem. Apart from this the type of knowledge, particularly tacit knowledge gained through experience and learning over time is hard to be coded and also people are not often aware of the knowledge they possess or its value for others. All these make the task of finding trustworthy experts for an investment decision more complicated and challenging. With the objective of developing a trust based investment relationship, we propose a social network approach making use of Mutual Fund Investment Portfolio. It is generally believed that pursuing an investment decision of a trustworthy mutual fund is less risky than seeking advice from an individual expert. We can also examine the credibility of investment behaviour and stock holding patterns of the mutual fund in real time and a stock recommendation system, namely, *trust based stock recommendation system*, showing the leading stocks appropriate for investment can be designed. Such system can also show the investment price range by analysing the mutual fund transaction in the stock market reducing the overall risk and increasing the profitability. In order to demonstrate the acceptability and reliability of the proposed methodology, we have carried out an detailed analysis of this model on CRISIL-1 rated Indian Mutual Funds. The results of this analysis strongly support the validity of the proposed portfolio recommendation model.

2. Stock portfolio recommendation system

Generally a recommendation system suggests personalized choices from a large set of possible options with the objective of reducing complexity decision making⁶. The last decade has witnessed the emergence of lots of e-commerce portals offering such services to their users. Generally a recommendation system works on information filtering technique and provides information which is of the interest of the concerned user. Typically, a recommendation engine, which employs a set of algorithms, compares the user's profile

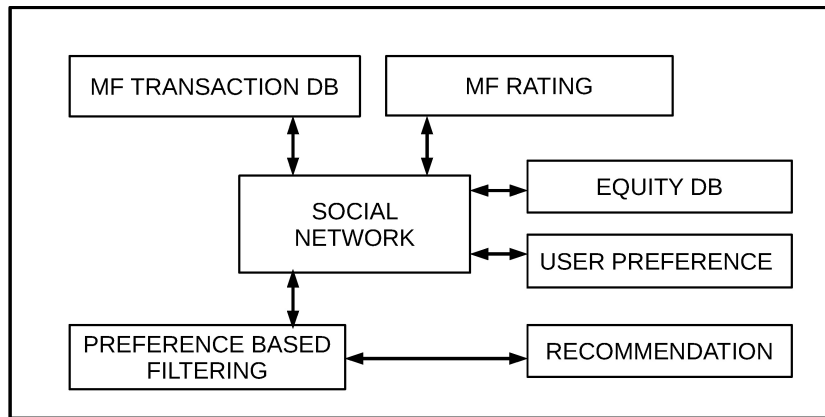


Fig. 2. The model architectural framework of the proposed recommendation system.

to some reference characteristics collected from the information item (the content-based approach) or the user's social environment (the collaborative filtering approach), and seeks to predict the most suitable item for a particular user.

The methodology proposed for stock portfolio recommendation system in this work aims at enhancing the profitability opportunity associated with stock portfolio recommendation by anchoring on the trustworthiness of mutual fund portfolio network. We could gain insight into the social investment relationships exist among stocks, which are otherwise hidden. By identifying the position of individual stocks we could determine the centrality associated with stocks in the entire portfolio network. Finally, a recommendation of a stock is offered matching the investor preference in creating a portfolio to the most relevant stock in the network. This kind of trust based social network recommendation system could be beneficial to both novice investors and first-time investors equally. The user is provided with a portfolio of relevant stocks in sync with their matched priorities. The mutual fund portfolio network is represented by means of a bipartite graph as depicted in Fig. 1, where set of nodes U represents the mutual funds and set of nodes V represents stock invested by the mutual funds. An investment by a mutual fund in a particular stock is represented by an edge. The edge between mutual fund and equity will provide insight about the total number of shares and the invested value which will in turn assist in understanding the average investment bracket. From the this two mode network(bipartite graph) we can derive the 1-mode network, with stocks as nodes, using folding methods which operate directly on the matrix corresponding to the bipartite graph. Two stocks, in the 1-mode network of stocks, are connected if a mutual fund has invested in both the stocks.

Table 1. (a) The matrix showing Stock-Mutual Fund (SMF) Investment Matrix where S_i is the i^{th} stock, MF_j the j^{th} mutual fund and $SMF_{i,j}$ assumes values 0 or 1 depending on whether the j^{th} mutual fund invested in i^{th} stock. (b) The matrix showing Stock- Stock (SS) Investment similarity Matrix

| | MF ₁ | MF ₂ | ... | MF _n | | S ₁ | S ₂ | ... | S _m |
|--------------------|--------------------|--------------------|-----|--------------------|----------------|-------------------|-------------------|-----|-------------------|
| (a) S ₁ | SMF _{1,1} | SMF _{1,2} | ... | SMF _{1,n} | S ₁ | SS _{1,1} | SS _{1,2} | ... | SS _{1,m} |
| S ₁ | SMF _{2,1} | SMF _{2,2} | ... | SMF _{2,n} | S ₁ | SS _{2,1} | SS _{2,2} | ... | SS _{2,m} |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| S _m | SMF _{m,1} | SMF _{m,2} | ... | SMF _{m,n} | S _m | SS _{m,1} | SS _{m,2} | ... | SS _{m,m} |

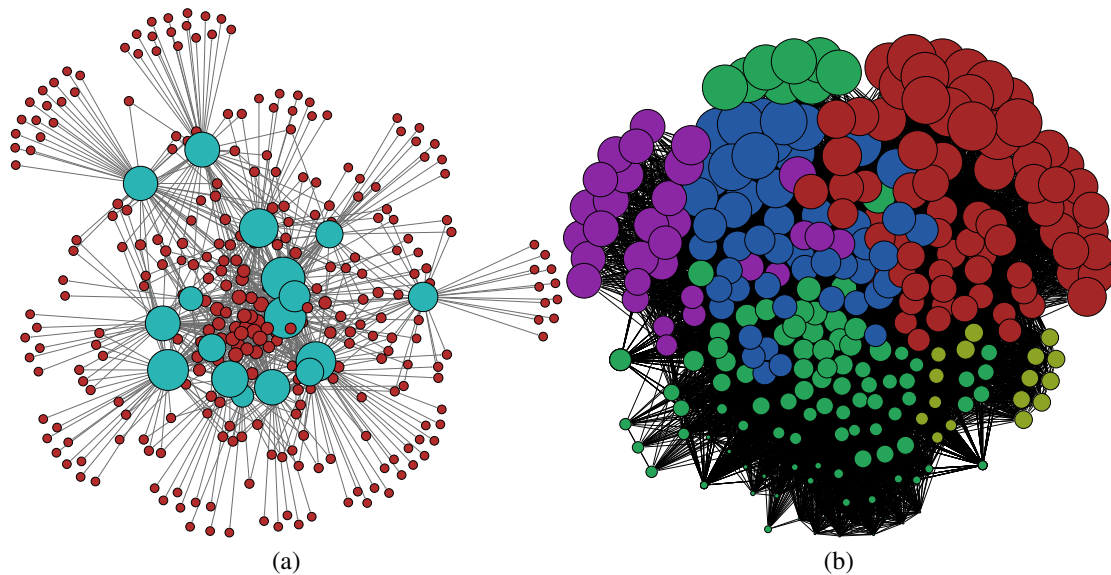


Fig. 3. (a) Visualization of 2-mode network of mutual funds and stocks. Cyan nodes represent mutual funds whereas the red nodes represent stocks. (b) Visualization of 1-mode stock network with clusters shown in different colours.

2.1. Architecture and technical frame work

A recommendation engine, based on the social network analysis approach discussed earlier, can be developed with components namely mutual fund portfolio, knowledge base of stocks and mutual funds, decision making logic which further consists of preferences and filtering methods. The overall functional architecture is composed of blocks shown in Fig. 2.

The *centrality measures* quantifies the degree of interconnection of nodes in a network. We have used both degree centrality and eigen vector centrality to find out relevant stocks in the network. The degree centrality is the simplest centrality measure which counts the number of ties that a node has with other nodes in the network^{7,8,9}. It is a measure of popularity. The eigen vector centrality of a node is measured on the centrality of its neighbours centrality which shows the influence in the network¹⁰. The relevance of a stock measured on these centralities depends on its popularity as well as influence. Based on the mutual fund transaction data, the average investment price is identified and it is compared with historical and current trading price of stocks to recommend the investment bracket for each stock.

Mutual Fund transaction database unit shows the current stock investment portfolio of mutual funds. Mutual fund rating unit stores the rating of Mutual funds by external agencies and ranks them based on their performance. Credibility of an mutual fund is measured by parameters such as performance, expertise, and dynamism. Equity database unit stores the information related to each stocks that traded in stock market such as industry and sector. The user preference unit stores the attributes detailing investors profile, which includes his goals, preferences and investment strategies (long term/short term or high risk/low risk). Based on the user preference, mutual fund portfolio is filtered and analysed in detail using tools of social network analysis. A filtering approach is administered in the network analysis, based on the sector (large, middle and small cap) and industry (finance, IT, pharmaceuticals etc.), and credibility of mutual funds (ranking undertaken by trustworthy external agency such as CRISIL) to identify each segment in the network and further portfolio stocks from each segment is identified using centrality measures. This can be summarized in the following steps:

- Capture the user preferences,
- Identify the trustworthy mutual funds by considering ratings provided by an external agency,

Table 2. Performance of Portfolio-1 based on Degree Centrality.

| Company | Sector | Buy Price | High | Low | Sell Price | Peak Gain (%) | Normal Gain (%) |
|-----------------|-------------------|-----------|-------|-------|------------|---------------|-----------------|
| Bajaj Finance | Finance | 2,064 | 2,235 | 1,661 | 2,213 | 8 | 7.20 |
| Hind Zinc | Metals & Mining | 160 | 184 | 121 | 167 | 15 | 4.38 |
| IndusInd Bank | Finance | 498 | 587 | 471 | 571 | 18 | 14.66 |
| LIC Housing Fin | Finances | 236 | 352 | 231 | 327 | 49 | 38.56 |
| Mindtree | IT | 673 | 958 | 648 | 878 | 42 | 30.46 |
| NMDC | Metals & Mining | 137 | 196 | 136 | 182 | 43 | 32.85 |
| Dr Reddys labs | Pharmaceuticals | 2583 | 2781 | 2246 | 2606 | 8 | 0.89 |
| Axis bank | Finance | 1453 | 2048 | 1766 | 1918 | 41 | 32.00 |
| Bata India | Consumer Durables | 1123 | 1295 | 998 | 1282 | 15 | 14.16 |
| Power Grid Corp | Utilities | 107 | 142 | 102 | 139 | 33 | 29.91 |
| Average | | | | | | 27 | 20.51 |
| CNX Nifty | CNX:NSE | 6721 | 7654 | 6652 | 7611 | 13.88 | 13.24 |

- Extract the detailed investment portfolio of each trustworthy mutual fund based on user preference,
- Construct a 2-mode network of Mutual Fund-Stock from the portfolio,
- Construct 1-mode network of stocks utilizing folding methods,
- Analyse the relative position of individual stocks in the network structure using centrality measures,
- Recommend the stocks to the investor in sync with their preferences and centrality characteristics.

The investment matrix of the 2-mode network of Stock-Mutual Fund is given in Table 1(a) where rows represent the stocks and columns represent mutual funds. The values of $SMF_{i,j}$ is 1 if the j^{th} mutual fund has invested in i^{th} stock, otherwise 0. Product of the matrix in Table 1(a) and its transpose will give the Table 1(b) which represents the 1-mode network of stocks. It reflects the influence of stocks in the original two mode network. The effectiveness of the proposed method is experimented with Indian mutual fund data.

3. Experiments

In order to demonstrate the performance of the above methodology in recommending trustworthy stocks, we have carried out an detailed experimentation basing on CRISIL (most trusted external rating agency in India) Rank-1 Indian mutual funds. For this purpose we have collected data from 17 mutual funds which have CRISIL rating of 1, as on March 2014 (quarter ending). The stock investment portfolio covers a wide range 288 stocks from varied sectors having greater than 792 investments (edges in the corresponding graph). The primary goal of this experiment is to assess the effectiveness of the proposed recommendation system for duration of a financial quarter (01 April 2014 to 30 June 2014). After the portfolio information is extracted, the 2-mode and 1-mode networks were formally constructed using the software packages Pajek and Gephi^{11,12}. The 2-mode network of mutual funds and stocks is given in Fig. 3(a) and the derived 1-mode network of stocks is plotted in Fig. 3(b). The centrality measures were then calculated for each node in the 1-mode network of stocks. The top 10 stocks based on degree centrality (Portfolio-1) is given in Table 2 and the top 10 stocks based on the eigen vector centrality (Portfolio-2) is given in Table 3 along with corresponding Nifty index in last row for comparison. These portfolios give the performance and effectiveness of proposed recommendation engine during that quarter by considering 1) closing price on 1 April 2014 which is considered as the buying price. 2) closing price on 30 June 2014, which is considered as the

Table 3. Performance of Portfolio-2 based Eigen Vector Centrality.

| Company | Sector | Buy Rate | High | Low | Sell Rate | Peak Gain (%) | Normal Gain (%) |
|----------------|-----------------------------|----------|------|------|-----------|---------------|-----------------|
| ING Vysya Bank | Finance | 615 | 673 | 537 | 649 | 9.00 | 5.53 |
| ICICI Bank | Finance | 1185 | 1593 | 1202 | 1418 | 34.00 | 19.66 |
| Tech Mahindra | IT | 1802 | 2161 | 1676 | 2132 | 20.00 | 18.31 |
| Motherson Sumi | Automotive | 254 | 327 | 245 | 321 | 29.00 | 26.38 |
| Reliance | Oil & Gas | 934 | 1145 | 925 | 1015 | 23.00 | 8.67 |
| HDFC Bank | Finance | 731 | 856 | 707 | 821 | 17.00 | 12.31 |
| Larsen | Engineering & Capital Goods | 1266 | 1776 | 1242 | 1685 | 40.00 | 33.10 |
| Federal Bank | Finance | 92 | 135 | 86 | 131 | 47.00 | 42.39 |
| Maruti Suzuki | Automotive | 1922 | 2528 | 1866 | 2428 | 32.00 | 26.33 |
| Bharti Airtel | Services | 313 | 367 | 305 | 335 | 17.00 | 7.03 |
| Average | | | | | | 27.00 | 19.97 |
| CNX Nifty | CNX:NSE | 6721 | 7654 | 6652 | 7611 | 13.88 | 13.24 |

selling price 3) low and high value during this period. Table 2, based on degree centrality, demonstrates that Portfolio-1 gives average normal gain of 20.51 % to its investors. Table 3, based on eigen vector centrality, demonstrates that stocks in Portfolio-2 gives average normal gain of 19.97 % to its investors. Both portfolios based degree and eigen vector centrality suggest almost same return. In order to assess the reliability of these recommendations we compared them with the performance of Nifty index during the same period and found that performances of these two portfolios are better than the overall performance of Nifty index during the same period reiterating the efficiency of the proposed recommendation framework. It can be seen that the corresponding Nifty index offer comparatively less return. In short, the hidden relationships among stocks have greater influence on the degree of accuracy of reliability of portfolio recommendation which in particular have a significant impact on the short-term profitability.

4. Conclusion

In this paper, we demonstrate that mutual fund transactions with an augmented assistance of social network analysis can be utilised to build a trustworthy stock market portfolio recommendation system. We show that trust based stock recommendation system is an effective approach to find trustworthy stocks based on credible mutual fund investment patterns giving high returns. Further, it may be noted that the trust-based investment decisions can easily be extracted from the model using social network analysis. The mutual fund credibility is a valuable parameter in calculating the items reputation. The paper demonstrates the efficiency of the performance of the proposed model in providing accurate recommendations by comparing with Nifty index. In short, it can be concluded safely that this methodology is a reliable portfolio recommendation system for a novice investor who is seeking well-informed investment guidance and this captures investment similarities exist between mutual funds.

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