B. Comp. Dissertation

Analytics Systems for Anti-Money Laundering

By

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2010/2011

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Abstract

The use of automated analysis tools for data mining in the field of fraud detection has become increasingly popular over the past few decades as a result of the growth in data volumes. This project describes our approach to learn and detect patterns in relational data using a graph representation. We have developed a web application which allows users to search for suspicious patterns in relational data through graphical query creation. Our application uses graph-based mining to analyze the query pattern consisting of relational links among clients and companies with the purpose of finding matching sub graphs in the data. The system can discover unknown and known patterns in data in the domain of anti-money laundering. This could be a useful tool for credit card companies in dealing with fraud prevention and monitoring.

Keywords:

Data Mining, Pattern Recognition, Anti-Money Laundering

Implementation Software and Hardware:

Windows 7, Adobe Flash Builder 4.0, Flex 4, Action Script 3.0, PHP, Apache HTTP Server, MySQL Database

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This final year thesis has been written at the National University of Singapore. My topic, which was part of a more comprehensive project at the Institute for Infocomm Research (I2R), has been both enriching and challenging. The experience I have obtained from this project is priceless to me. I would like to take this opportunity to express my gratitude towards some people who have significantly helped me throughout this final year project and beyond.

First, I would like to thank Professor Wong Limsoon at National University of Singapore for his valuable supervision during this project. I would like to express my regards to Mr Soh Cheng Lock Donny and Mr Tew Kar Leong from I2R for their generous help, discussions and guidance in shaping the project. I also thank Miss Luo Xueqi Annaliese at Fusionopolis and Miss Pamela Lim Mai Fun, Miss Tan Poh Suan at National University of Singapore for coordinating this Final Year Project for their help in managing the administrative affairs.

Lastly, this project would not have been possible without the huge contribution of my classmate Linxiang Du who worked on this project along with me.

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Chapter 1

1. Introduction

1.1 Objective

Money laundering is a way by means of which people, groups or organizations can conceal the origin or destination of their financial transactions. Traditionally, these transactions are not transparent and hence the practice is illegal. Most financial institutions, for example, credit card companies, today are faced with issue of combating this serious problem. These companies have a requirement to monitor and report transactions of a suspicious manner to an investigation unit. For instance, a credit card company should verify every customer's identity and track their transactions for possible fraudulent activities such as money laundering. For this purpose, these financial institutions collect data about their clients and their transactions.

Data mining applications are often deployed in this field since the amount of data to be scrutinized is vast. Often the relevant information is hidden within massive amounts of irrelevant data and appears harmless when studied individually (K. A. Taipale, 2003). Traditional methods of information retrieval from a relational database using simple SQL queries alone are not capable of detecting such hidden patterns. Hence, the need for data mining arises to discover new knowledge in existing data.

This project explores the use of graph-based data mining in anti-money laundering practices. We have developed an application which uses such analysis for fraud detection by recognizing patterns within a prevalent set of relational data. A user can define a desired query graph pattern to detect a potential money laundering activity and the system will provide the data that matches such a pattern.

1.2 Chapter Guide

Chapter 2: Background

This Chapter includes a brief definition of the problem at hand and the data mining technique we use in this project. We also discuss the motivation and the applications of our project in the finance industry.

Chapter 3: Design

This Chapter provides an overview of our proposed approach with illustrative examples. We also discuss the interface design criteria used for this project and short description of the searching algorithm used for this project.

Chapter 4: Implementation

This Chapter describes the selection of software specifications, the creation and design of the user interface and other aspects of the implementation phase of the project.

Chapter 5: Analysis

This chapter provides an analysis of the project in terms of its overall performance. We discuss user feedback obtained and present a comparative study of the software with relevant existing work.

Chapter 6: Summary

This chapter provides a summary of the entire project with a conclusion.

Chapter 2

2. Background

2.1 Problem Definition

The application of automated analysis and knowledge discovery helps to reveal relationships among data that was earlier unknown and may be potentially useful. A significant problem in data mining for fraud detection is that often the relevant information is hidden within vast amounts of irrelevant data and appears harmless when studied individually. With the rapid increase in the amount of data collected by companies on activities of their customers, it is sensible to utilize the massive volumes of data with a tool which automatically analyses and extracts useful knowledge from it.

In the context of financial fraud detection, the purpose of data mining is to isolate frequently repeated patterns of activity (for example, not paying taxes) which may help organizations in further predicting and tracking down future suspicious behaviour. Simple methods of information retrieval for identifying unusual activity in data may not be as useful in the current world as much of the information may go unnoticed when studied in isolation or may in fact hold no meaning unless studied in relation of their link to other data.

Therefore, to discover useful patterns in data the systems must uses existing databases containing customer information and employ advanced mining techniques to identify and analyze known and unknown patterns. One such technique is graph-based mining.

2.2 Motivation

This project led to the development of a system to sieve out fraud circles by filtering their relations with other entities in the dataset. This project can be further improved and used in banks in order to allow banks to adhere to their KYC (Know Your Customer) and AML (Anti Money Laundering) compliances.

The main goal for this project sprung from a desire this solve an important real-world problem. Additionally this project is an excellent platform to get a first-hand experience of the crucial skill of product design. This project was an ideal opportunity to develop a broad understanding of interfacing between business needs and technological capabilities.

2.3 Possible Uses

The resultant program from this project and the techniques used to achieve this have several possible uses. The application itself with further development would be a useful tool for pattern recognition and to help financial organizations in detecting and preventing fraud. The techniques used in our application would be useful for other similar applications. With some modifications, the application would be even usable on mobile devices and PDA. Overall, this project and its research have many benefits for future development.

Chapter 3

3 Design

3.1 Proposed Approach

The data that we use for our project has been obtained from a bank, and consists of “anonymized” information about real clients (both people and companies) and the relationship among these clients. The data is stored in SQL as a relational database in binary form. In this project, we use a graph query representation to provide an effective visualization of complex patterns.

A node in the query graph is an entity that the user is searching for, e.g. a person or a company and a connecting edge implies a relation between two entities. The nodes have defining attributes and the edges have types. For example, a “person” node can have attributes like: First Name, Last Name, Position, Passport Number and so on. Similarly, an edge between a “person” node and a “company” node may have the type “Founder” implying that the person is a founder of the company. The purpose of attributes is to help the user specify details of a pattern they are looking for. In such a setting, we want to find sub graphs that match a user-defined query pattern.

3.2 Illustration of Examples

In this section we construct some examples to demonstrate how our system will analyze scenarios with different structures of query graphs:

- Graph with a single node

Figure 1 Graph with a single node

In this example, the user is looking for a pattern of people who satisfy the attributes specified for “person” node A. These attributes may be the person’s title, location, country of origin and so on. This node could even be a company where the attributes would be different. In this case, our application will query the database for people who match this pattern in terms of the attributes alone, irrespective of their relation with other data.

- Graph with a single relation and two nodes

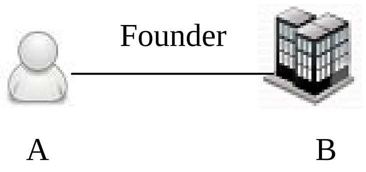


Figure 2 Graph with a single relation and two nodes

In this example, the user is looking for a pattern where a person has founded a company. Similar to above case, the user may further specify the attributes for the two nodes which will further provide more relevant results. In this case, our application will query the database for a person-company pair which matches this pattern in terms of the attributes and the relationship “Founder”.

- Graph with a several nodes and relations

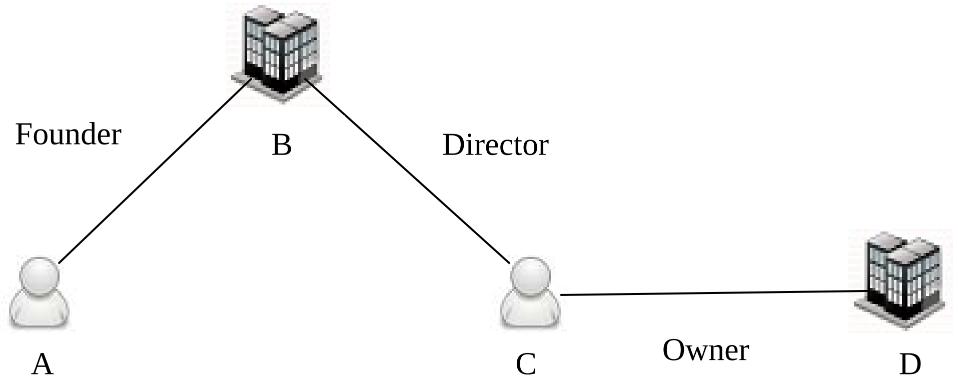


Figure 3 Graph with several nodes and relations

In this example, suppose we have the following attributes for the nodes above:
A: Is the “Founder” of company B
B: Is a company located in Singapore
C: Is a “Director” at company B who owns company C
D: Is a company in Japan

For such a graph, the script on the application server will search for each relation that is represented as a connection between two entities. The query output is then consolidated to form a further reduced set of results.

Similarly, another query could help spot a money laundering circle. Although it seems feasible to use standard SQL to address this problem, if exact match does not exist, SQL will not be able to approximate an answer. On the other hand, if there are many exact matches in SQL, it would be worthwhile to automatically rank them in order of a scoring function. In some cases, exact matching may not reveal the best possible answer. Our method can be improvised by ranking exact matches as well as the other connections present among nodes.

3.3 User Interface Design Criteria

In any software, the graphical user interface (GUI) is the first thing a user will see when he/she run the application and hence it is extremely important for the interface to attract the user’s attention. The second most important factor for a GUI is to be intuitive or easy to use. The design of a system which is intuitive and efficient depends on a variety of factors including usability, performance, reliability, functionality, innovation among others.

In the recent years, more emphasis is being laid on the quality and usability of web user interfaces. Since all software is made for a certain target group of users, it is essential that the intended users be able to understand the basic functionality of the software and use the menus and interface without a manual. If the graphical user interface is not intuitive and efficiently designed, the software isn’t likely to become very popular.

For this project, the GUI was a very significant part. As this project is concerned with constructing and editing graphical query structures, it was necessary that the GUI be user-friendly and simple. It is for this reason that in the early stages of the development cycle, a research was conducted to assimilate the essential and important features for designing a good GUI. A strong emphasis has been laid on the conceptualization and prototyping of the interface before delving into the implementation. To evaluate the initial design, a consultation was carried out with the help of research papers and feedback. We wanted to make out interface interactive and simple while maintaining high coding standards.

To develop a user interface for this project we decided to follow available principles on user interface design and summarize the common criteria listed in the selected papers we studied. The three main principles which must be followed to design a good user interface (John D. Gould and Clayton Lewis, 1985) are:

- Early Focus on Users and Tasks

  As a designer, it is important to identify the users of a system and the scope of the field the software will be used in.

- Empirical Measurement

  The use of prototypes and mockups during development phase is a good practice.

- Iterative Design

  The software must be tested and fixed in small cycles as the development proceeds. The paper mentions that iterative development cycles.

While these principles are helpful and intuitive, they are not enough to ensure a good interface design. These guidelines only direct the designer's attention to the common issues which must be considered. In reality, however, there is no one approach to user interface design. The user interface features depend on each individual system and the intended users. A good design maintains a trade-off between several conflicting features.

3.4 Graph-mining Algorithm

Given a query pattern like below, our algorithm will match the pattern with the entire set of the relational database and output the resulting sub graphs which match the pattern.

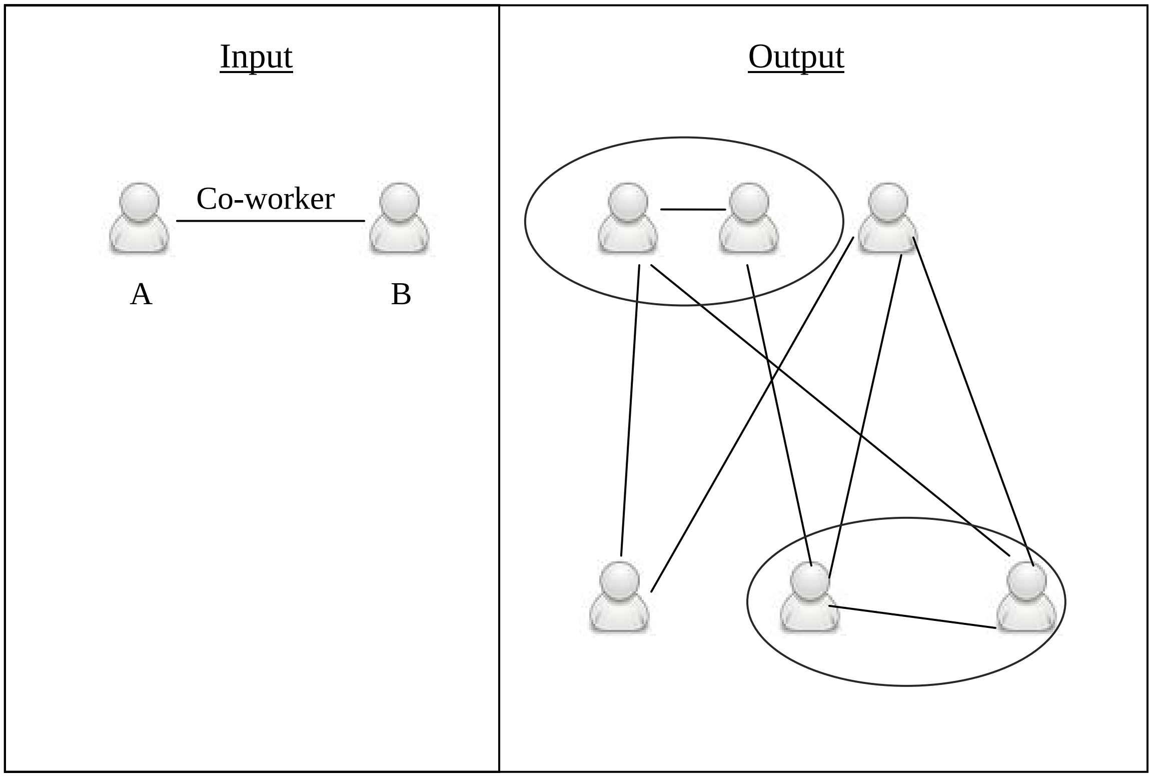


Figure 4 The input and output format of our graph-mining algorithm

In the example shown, the left column indicates the query graph pattern. On the right, the circled pairs of nodes are the matching sub graphs in the database that form the output of the pattern recognition algorithm in our application. As we can observe here, the input does not need to be complete graph but in the actual database, there may be other relations to this sub graph.

Chapter 4

4 Implementation

4.1 Application Setup

The data for our application is kept back on the application server and the necessary processing for the user interface is done on the web client. The scripting at the server end is done using PHP. We use an Apache HTTP server for our application deployment. The interface is developed on Adobe Flash Builder IDE using a programming language (Action Script), an XML language (MXML) and the Flex library. The following diagram provides a better overview of how the application was developed:

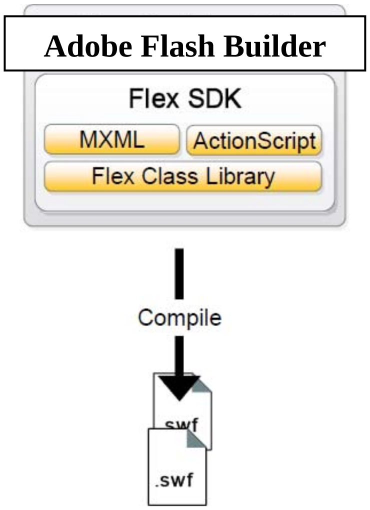


Figure 5 Compilation process from Adobe Flash Builder IDE to Flash .swf

The application can be run in a web browser and hence does not require any software installation. So far, we have tested the interface to work on the following browsers: Internet Explorer, Google Chrome, and Mozilla Firefox.

The browser must have Adobe Flash Player installed on it so as to be able to use our application. The interface communicated with the web server through the browser and the internal exchange of data is done by using the HTTP Service in Flex. The components used for developing the interface were obtained from various Flex libraries.

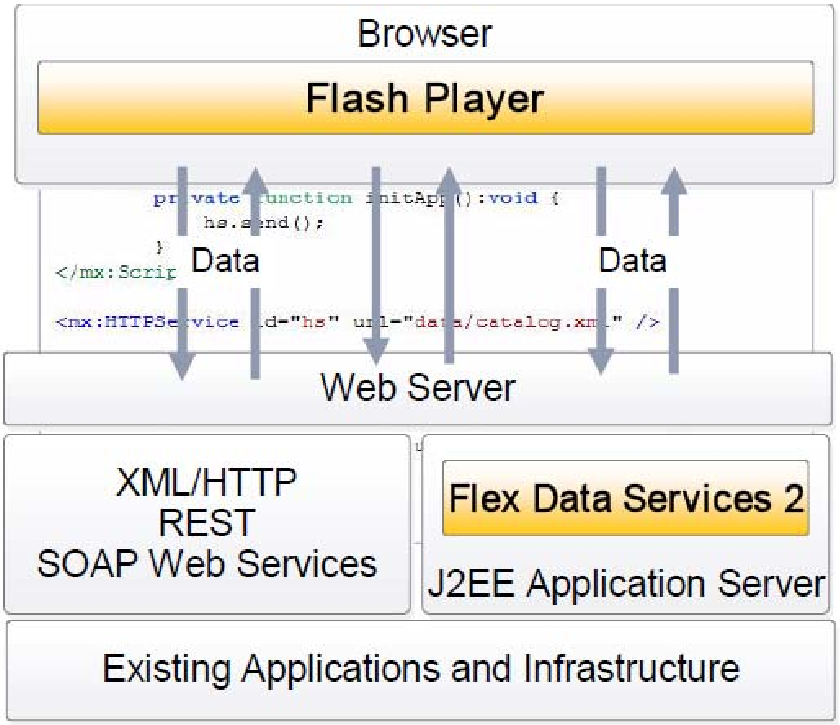


Figure 6 Architecture diagram of the application

4.2 Application Workflow

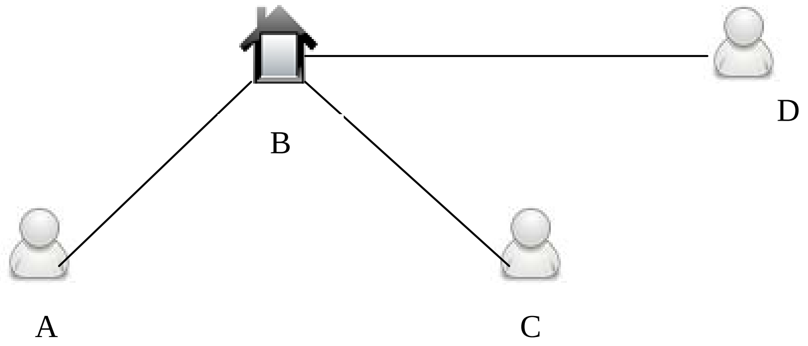


Figure 7 Sample Query Graph

Let us consider the example attributed query graph shown above. Given this graph, we want to find all such entities in the database where this pattern applies. Once the user has created the above query graph in the interface and specified the relations, he/she can then search for this pattern in the database.

This can be done by clicking a search button on the left accordion panel. When the user clicks this button, an ActionScript method is called which will generate the XML document for the query and invoke the PHP script on the application server. Each link between two entities in the query graph represents a relation that the script would query the database for. For a given set of relations the script would individually query each relation and take the union of the results obtained to form the final output. For example, the relations to search for in this graph are A-B, B-C and B-D. These results are then consolidated using a join algorithm in the PHP script to form sets of matching data.

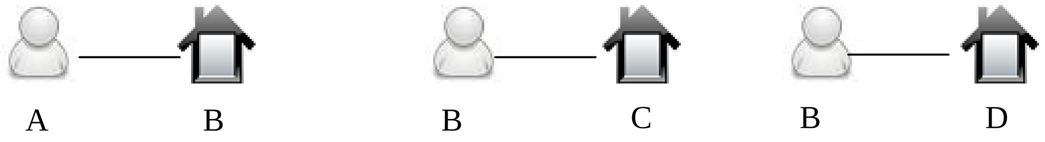


Figure 8 Pairs of relations searched at the backend for forming results

The query data is passed to the application server as an XML file with parallel structure. The information is passed as node pairs that form a relation and nodes may be repeated for various relations that it is a part of. A sample relation tag node is shown here:

```
<relation>
        <type> Founder</type>
                <company>
                        <Tag>Node1</Tag>
                        <Name> … </Name>
                        <Type> … </Type>
                        <Industry>…</Industry>
                        <Location>Singapore</Location>
                        <Found_Year> …. </Found_Year>
                        <Employees>…. </Employees>
                        ……
                </company>
                <person>
                <Tag>Node2</Tag>
                <Last_Name>… </Last_Name>
                <First_Name>… </First_Name>
                <Position>… </Position>
                <Age>…</Age>
                …….
        </person>
</relation>
```

Figure 9 Structure of XML file passed from the interface to the backend

4.3 Graphical User Interface

In this project, we mainly focused on two features of the user interface: presentation and usability. The presentation of the data in an understandable manner is much more valuable than putting the data onscreen and letting the user try to decode it. As one of my main contributions to the project was designing the user interface, I was working extensively to create mock-ups for the interface and rework on the initial interface design.

4.4 Iterative Development of interface

In order to demonstrate that the interface for this project went through an evolution cycle before it reached its final design, two particularly significant designs are included. In the two figures displayed below, the first one is the original design and the second is the modified final design. While both the interfaces were developed with the intent of simple and functional design, the second is much more refined and interactive.

In the figure below, the drawing area provided to the user for the graph is quite small and much of the screen space is not effectively utilized. The layout seems quite plain and not very intuitive. The table on the right side of the interface was meant for displaying the results of the searched patterns.

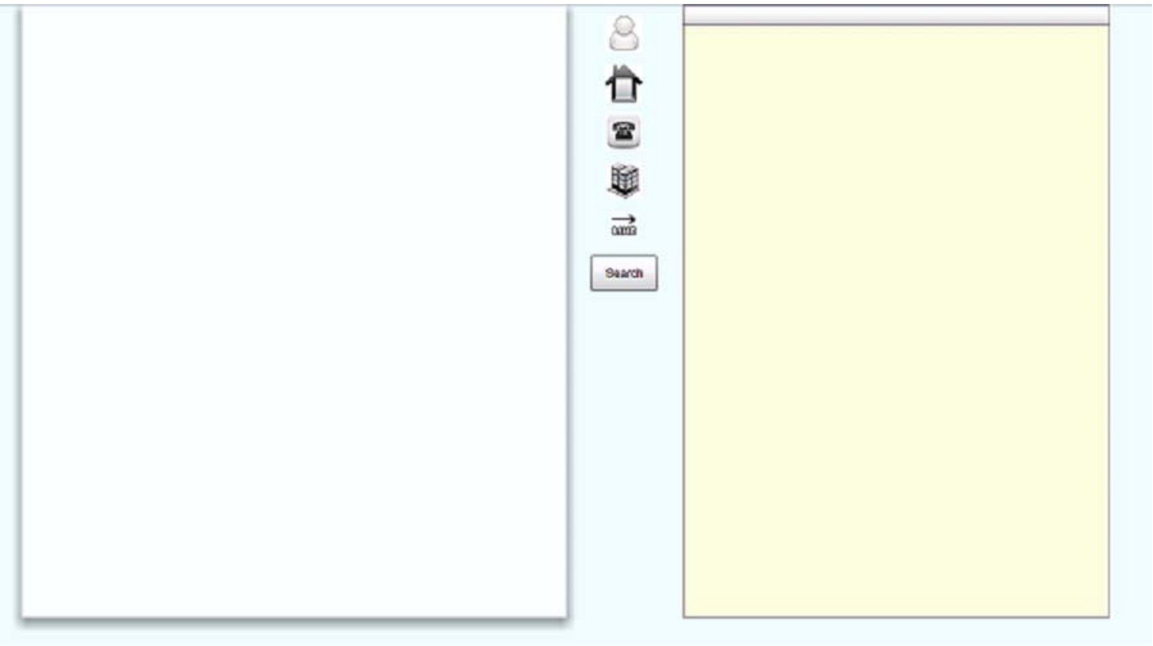


Figure 10 Initial interface of our application

In the later stages of design, much of the similar user interface elements were consolidated. This helped to produce a cleaner design with little clutter and more space for the user to draw the graph. We used collapsible accordion panels for rich interactions.

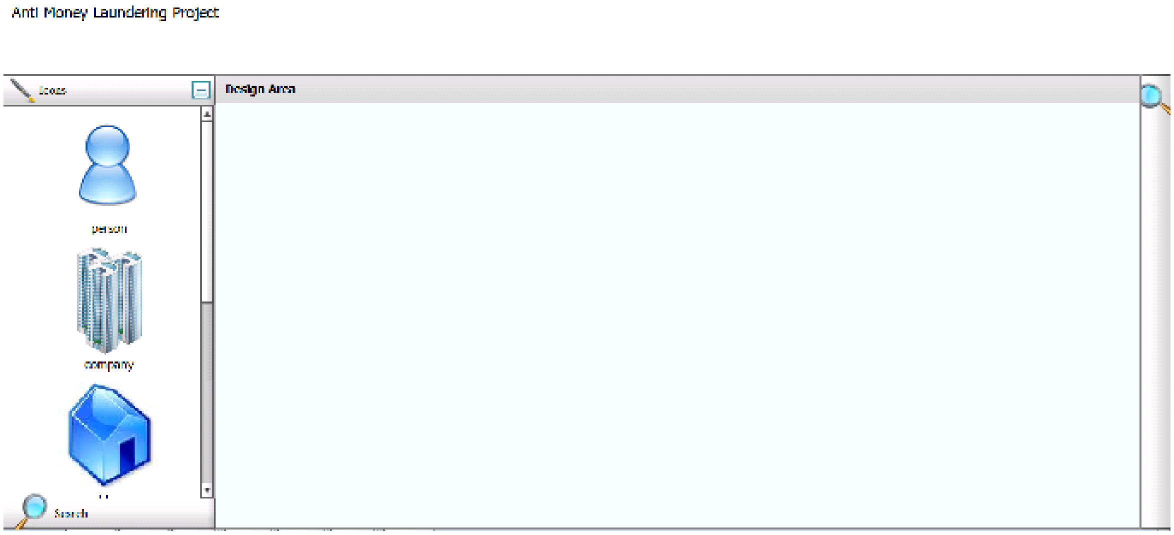


Figure 11 Final Interface of our application

Chapter 5

5 Analysis

5.1 Results and Interpretation

In the initial stages of development, we created a web interface which communicated with the database through a method called URL passing. In this method, the query information is appended to the URL string. On the server, a PHP script simply extracts all the information from the URL uses the information to form a SQL query. The obtained results were passed back to the web interface encapsulated in XML format. With a complex relation graph, there are more than one ways to interpret it and each different interpretation may lead to a different set of expected results.

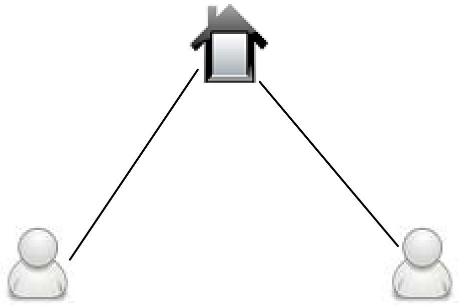


Figure 12 Graph query of two persons living at same address

In the above example, we have a query graph with a house where two people live. This graph can be decomposed into two person-house relations with all the information constraints specified. Our interface will identify all houses with at least these two people in it and each of the people must satisfy the criteria mentioned.

With a complex relation graph, there are more than one ways to interpret it and each different interpretation may lead to a different set of expected results. For instance, in the example shown earlier there is another possible interpretation. The example can also be interpreted either as a house that has exactly these two people living in it and no more. In this interpretation, we are also concerned with other members living in the house. Thus, it is evident that the interpretation varies with the focus of a query. If we are searching for all the people that share a house with a particular person, instead of querying for a house that accommodates only these two people, the number of people living in the house would be irrelevant. In our final implementation, we have used the interpretation described in example below as it appear more intuitive to us:

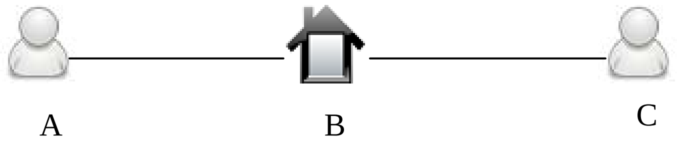


Figure 13 A relation graph with 2 persons and 1 Address

The above graph has entities {A, B, C} with edges {A, B} and {B, C}. In our interpretation, A! = C. There may be other entities that are not included in this graph which have relations with these entities but we are not concerned with those since that has not been specified in this query. For example, there may be another person D also living at the same address, where A! = D and C! = D.

5.2 User Feedback

As we have used graphs as a visualization medium in our project to make it more user-friendly, it is important to consider whether the interface and medium used in our project is intuitive and expressive. These features help us to evaluate the overall usability of our application and help guide us in the path for future improvements. We asked users to record the response time for certain graphs and based on their data, below is the indicator of our application's performance:

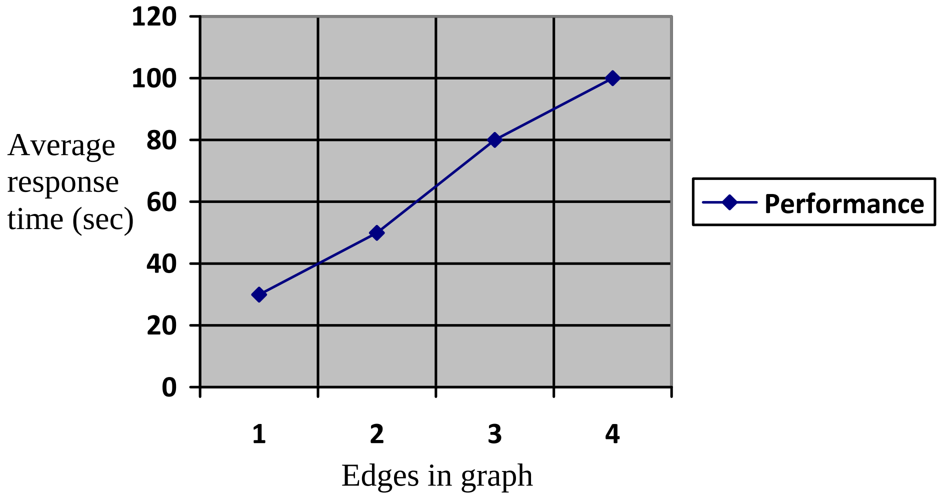
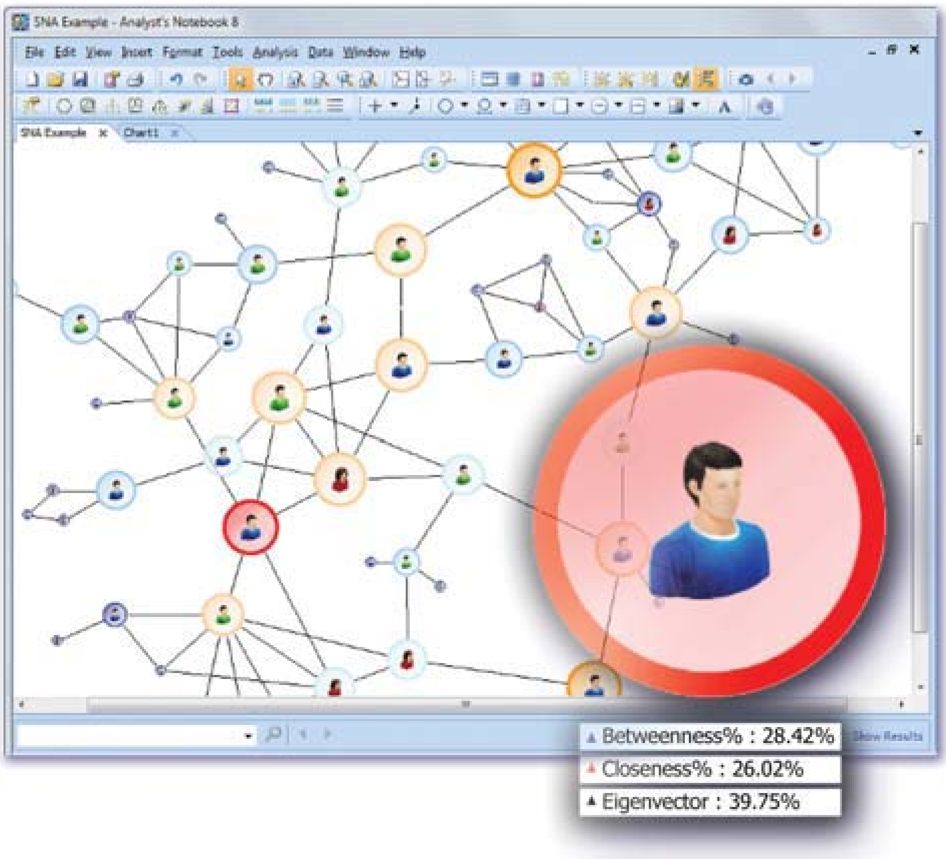


Figure 14 Average response time vs. number of edges

We discovered that on the whole, first-time users were quite satisfied with most of the features and performance of our application and found it easy to learn and use. The focus of future development in this project should be based on the areas where users find less satisfying and still use often. This user feedback exercise helped us to collate qualitative information regarding further improvisation and a review of the application interface from a user perspective.

5.3 Related Work

We have found that a company named i2 (a provider of intelligence and investigation management software for defense and security) has done similar work in the area of financial fraud detection. Their fraud solution helps analysts to search multiple data sources simultaneously, find hidden links and entities, and visualize transactions and timelines.


SNA Example - Analyst's Notebook 8
File Edit View Insert Format Tools Analysis Data Window Help
SNA Example
Chart1
Show Results

▲ Betweenness% : 28.42%
▲ Closeness% : 26.02%
▲ Eigenvector : 39.75%

Figure 15 An i2 product to identify key individuals within target networks with Social Network Analysis

The technique they have applied is social network analysis (SNA). SNA is an approach where the structure of relations among entities such as people, organizations, and locations and so on is examined. It emphasizes on the linkages between these nodes and is geared towards uncovering patterns of interaction in these linkages. The most distinguishing feature of this technique is the assumption that all people are interdependent. It is possible to unveil the structure of a network by observing the relational patterns among entities. Similarly, the same idea can be extended to a criminal network where a relationship between nodes aids in identification and detection of patterns in communication.

The study of social networks and linkages can prove particularly helpful in the credit card industry in combating collaborative fraud circles. SNA can be utilized to reveal fraud patterns based on the information that links fraudsters and help to reveal hidden criminal connections. This produces a more sophisticated fraud detection process. An interactive reporting system enables investigators and analysts to query data and search for interesting or unusual connections.

Another related paper on pattern-matching in attributed graphs (H. Tong et al., 2006) uses an algorithm which searches for inexact matches based a graph input pattern. The paper describes a method where near-matches are returned and ranked in order of “goodness”. This is a feature which we wanted to incorporate in our application as a scoring function. However, it is still in development at this stage.

Chapter 6

6 Summary

6.1 Problems Encountered

In the development phase, we encountered situations where certain scenarios could be represented as a network on the interface but proved challenging to query with our scripting algorithm. While we are able to successfully match positive patterns in the data, finding outliers posed an enhanced level of difficulty.

For example, if we want to find all the people in Germany who have never paid taxes, we would need to modify our interface to incorporate negated relations between nodes.

The outlier detection approach tackles this problem better as it is designed for identifying unusual patterns in data (Martijn Onderwater, 2010). While such scenarios are not so challenging to represent visually, to process it in the server requires significant modifications in our existing algorithm in future.

6.2 Limitations

In this section, some of the main limitations of the approach used in this project are described.

- Inaccuracy in data

If the data collected in the database be incomplete, the accuracy of the discovered patterns can be compromised. Data cleaning techniques, more sophisticated statistical methods to identify hidden attributes and their dependencies, as well as techniques for identifying outliers are therefore required.

- Presentation of the discovered patterns

In most of the applications, it is important to represent the discovered patterns in more human understandable form such as visual or graphical representation. In this project, we did not have sufficient time to develop a sophisticated representation technique for displaying our results and hence we used a simple table representation.

6.3 Recommendation for future work

In this section, some areas for improvement of our project are described.

- Adaptability for constantly evolving data and knowledge base

In the context of credit card companies, the transactional data collected is increasing on a daily basis and hence it may render some previously discovered patterns invalid. Also, the attributes recorded for a given database may be changing with time. A good improvement would be to include incremental learning techniques to handle these cases. This may also be done by allowing a user to input the database to search for patterns in.

- Adaptability for different kinds of mining from the same data

Different users may be find different kinds of knowledge relevant depending on the context. Thus, it would be beneficial if the system could allow for a wider scope of analysis and pattern detection scenarios. The negation case described earlier would be a significant addition to the application.

- Ranking of results

For some query graphs there may be many exact matches in SQL. Our application does not implement any method to rank these results in order of relevance. Including a scoring function in the application would be a very helpful improvement to our algorithm.

6.4 Conclusion

We have presented an application that addresses the crucial problem of money laundering by finding relevant patterns of fraud given a large relational database. The main contributions of this work are:

- Instead of using traditional methods of data monitoring for fraud detection, we have proposed the application of a pattern-matching technique. We have explained why our method of approach is more relevant in the domain of fraud detection and we believe that it could be of key area of development in the future.

- We have introduced the significance of the problem that are we concerned with and provided examples to demonstrate how our system can be useful in this context.

With regard to future work on the system, we believe that system can be made scalable and improvised based on the suggested criteria so as to be of better use for the problem at hand. As the process of knowledge discovery is an interaction between a user and the data mining system, it is often difficult to ascertain the nature of the discovered information (S. Bandyopadhyay et al., 2005). Thus, in order to produce relevant and usable knowledge from a given dataset it is essential that the user be able to focus their search intelligently.

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Appendix A

How to install the program

To run the program, you will need to install a local Apache HTTP Server along with MySQL and phpMyAdmin on your computer. You may install them individually but we recommend using XAMPP. Alternatively, you can also deploy the application on your own web server. This application has been developed and tested in Windows alone, so there may be potential issues on other operating systems.

How to install a local server:

Please download the XAMPP installer from “http://www.apachefriends.org/en/” suitable for your operating system. Follow the steps to install XAMPP at a desired location on your computer.

How to set up the database:

Access the URL "https://localhost/security/xamppsecurity.php" to set the password for user "root" to "password". This is need to login to the database admin on the server.

To set up the required database for the application, please navigate to the URL "https://localhost/phpmyadmin/" and login with username as "root" and password as "password".

Once logged in, create a new database called "searchdatabase" and import the file "searchdatabase.sql" which is provided in this application folder.

Where to place the application web content:

The main directory for all WWW documents is \xampp\htdocs. Put the files "connection.php", "pairwise.php" and "initialize.php" in this directory.

Make a new subdirectory for the application (e.g. "Application") inside the directory "\xampp\htdocs". Copy all the remaining contents from folder “Search” on the CD to this subdirectory. You can now access and use the application by navigating to "https://localhost/Application/Search.html".

Appendix B

CD Contents

The attached CD contains a working version of the completed application. It also contains the source code for the program and instructions on how to install and run the program. The “Final Year Project” folder in the CD contains the following:

ProjectReport.pdf

A PDF version of this report, viewable in Adobe Reader.

Source Code folder

This folder the complete Adobe Flash Builder project files. These files can be imported to a new project in the Adobe Flash Builder 4 IDE and used for further development.

Installation Details Folder

This folder contains all the necessary files to run the application and instructions on how to deploy it on a web server. The following is a list of the folders contents in more detail:

Readme.txt

This file contains the same instructions as Appendix A on how to install a local web server and how to set up the application files on it.

Searchdatabase.sql

This is a script file which contains the schema of the database that is used by the application and the populated data as obtained from our industry partner.

Search Folder

This folder contains all the files, PHP scripts and images required to run the application on a local web server.