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Distributed Real Time PCM System, UML Design and Development with Embedded Programming

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Abstract This manuscript presents research conducted towards the proposition, design and implementation of an intranet hardware control and data management system. Solving the problem of automatically extracting print based information from each user system of a workgroup and managing that in an enterprise database management system, a new approach i.e. PCM System is proposed in this manuscript. PCM System is a platform independent distributed real time software application. It uses the concepts of system and embedded programming and implements a thread that provides a dynamic print look up service. The successfully achieved goal of this research was limited up to the retrieval of deployed plotter and printer's information from user system. Furthermore at user given print request, system snatches, transfers and saves processed information in the database with the help of an intermediate server system. Going into the details of the newly proposed approach, this manuscript portrays the network structure, provides some UML descriptions of implemented designs (including use case, data flow, flow chart, system sequence, class and component diagrams) and presents a graphical user interface of the application. Validating the potential of implemented approach, a case study is also described based on a real time scenario.

Keywords Distributed System, Real Time System, Embedded Programming, System Programming, Print Control, Hardware, Unified Modeling Language (UML)

1. Introduction

Designing and implementing a distributed real time embedded system involving any kind of software and hardware is always a challenging task for the designers and developers. To overcome the problems in resolving the challenge of creating an appropriate hardware oriented software application capable of monitoring plugged printing devices and automatically extracting print based information from each user system of a workgroup, and managing that using a database management system, a methodical research is conducted mainly in the fields of system programming[1], embedded systems[6], printer and plotter controlling[2] and network programming[3],[4].

System programming is also renowned as the low level programming methodology, the branch of software programming capable of providing services to control hardware devices. Using system programming concepts a programmer not only can control the basic internal hardware components of a computer (e.g. ports, display, memory etc.)[24] but can also direct plugged devices (e.g. keyboard, mouse, printers, universal serial bus etc) [35],[36].

Old, most recommended, commonly used system and embedded programming languages are Assembly[5] and C languages[6]. Furthermore, now days it's also possible to do system programming at some level using object oriented programming languages as well e.g. C++[6], Java[7] and C#[8] etc.

The focus of this research and development is first to solve the problem of extracting user's print based information, then save the extracted information into a database accessible to the administrator for further record keeping and data manipulation. In an intranet workgroup environment where multiple users are connected to one or many print servers can send multiple print requests to associated printers (including plotters). Many useful commercial print management software applications do exists e.g. *PaperCut*[19], *CZ Print Job Tracker*[20], *A.N.D. Pcounter*[21], *Cyclope Print Management Software*[22], *HP Web Jetadmin software*[23], *ObjectPrint*[32], *papercut*[33] etc., putting values in taking advantage in tracking print records to reduce print costs and increase environmental impact.

There is no such (freely available open source) solution available which can help in having the information (e.g. *user name, used printer, number of pages printed, job requested, time, date* etc.) about all sent print requests by all users along with explicitly provided dynamic real time

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product line architecture based relational data management system, offered, claiming to provide efficient data management of printed records in intranet workgroup environment.

The manuscript is organized as follows: going from a more general overview, section 2 describes the implemented PCM System. Section 3 presents UML[13][10] designs including Use Case (Section 3.1), Data Flow (Section 3.2), Internal Work Flow (Section 3.3), System Sequence (Section 3.4), Class (Section 3.5) and Component Diagrams (Section 3.6). Section 4 validates the potential of PCM System with the help of a case study of a real time scenario. Section 5 concludes the manuscript.

2. PCM System

Targeting the defined problem of automatically extracting print based information from each user system of a workgroup and managing that using a database management system, and following the concepts of system programming[1], printer and plotter controlling[2] and network programming[3],[4], proposed a new approach i.e. Printer Control and Management (PCM) System.

PCM System is capable of working in any (existing) implemented network structure, providing current view of connected print devices, monitoring printing, providing print history and notifying printing.

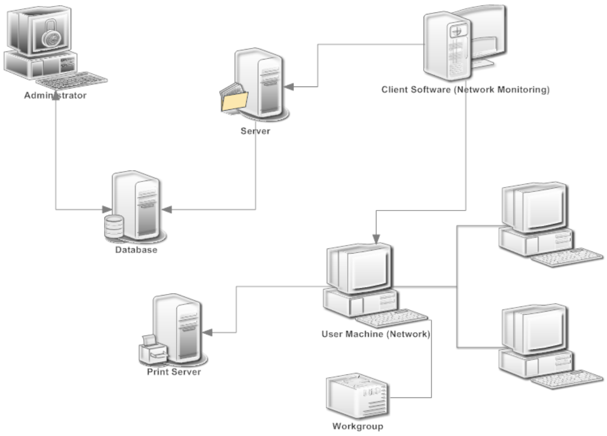


Figure Legend. Intranet Structure of PCM System consisting of three server machines: Server (Main/File), Database and Print Server, User connected machines (workgroup) and one Administrator machine

Figure 1. PCM System; Intranet Structure

PCM System is based on product line architecture[18], to make software application flexible enough to easily adopt future updates and additional features. The developed PCM System consists of three main modules: *Client, Server* and *Admin*. The client module is needed to be deployed in the user systems (intranet workgroup machines), a server module is needed to be deployed at main server and admin module is needed to be installed at administrator machine (Figure 1).

The client module is like a thread[17] working at user machine capable of tracing and providing all in use or provided printers and plotters. The client module is capable of getting information about physically attached printers (real time printers which prints the job on paper etc.) and printing engines (these are virtual printers e.g. Adobe PDF engine used to convert files of different formats e.g. word etc. into PDF format etc.). When a user will send a request to any attached printer (physical or virtual) then the client module will automatically snatch requested information and send to the server module.

Table 1. PCM System; Graphical User Interface Feature Description

No.	PCM System	
	Features	Descriptions
1	User name	Login name to login in to the database server.
2	Password	Login password to login in to the database server.
3	Host	Host information (e.g. IP address or direct name).
4	Set default host	In case admin is dealing with different database servers then he can fix the default using this option.
5	Login	Button to login in to the server (after having and validating all required information).
6	Refresh	Button to manually refresh the connection with database server.
7	User	“user name” to search for some particular name filtered record.
8	Date from	“date from” to search for some particular date filtered record.
9	Date to	“date to” to search for some particular date filtered record.
10	Retrieve	Button to retrieve records by pressing “Retrieve” button.
11	Total records	Gives the count of retrieved records.
12	About us	Button to have information about software version.

The job of server module is to receive sent data by the client module from user machine(s) and then save that in database management system located at the database server. The admin module (Figure 2) is the developed graphical user interface (GUI)[25],[26],[27] which allows user to connect to the database server to get server saved data and perform data manipulation operations. It mainly consists of some GUI features: *User name, Password, Host, Set default host, Login, Refresh, User, Date from, Date to, Retrieve, Total records* and *About us* (Table 1).

The job of Admin module is to let administrator connect to database server (using valid login name, password and host name), have all stored data and search particular records using provided filters. Additionally a security mechanism is also developed and deployed for the user, client and admin authentication, while logging, sending and receiving requests at servers (print and main both).

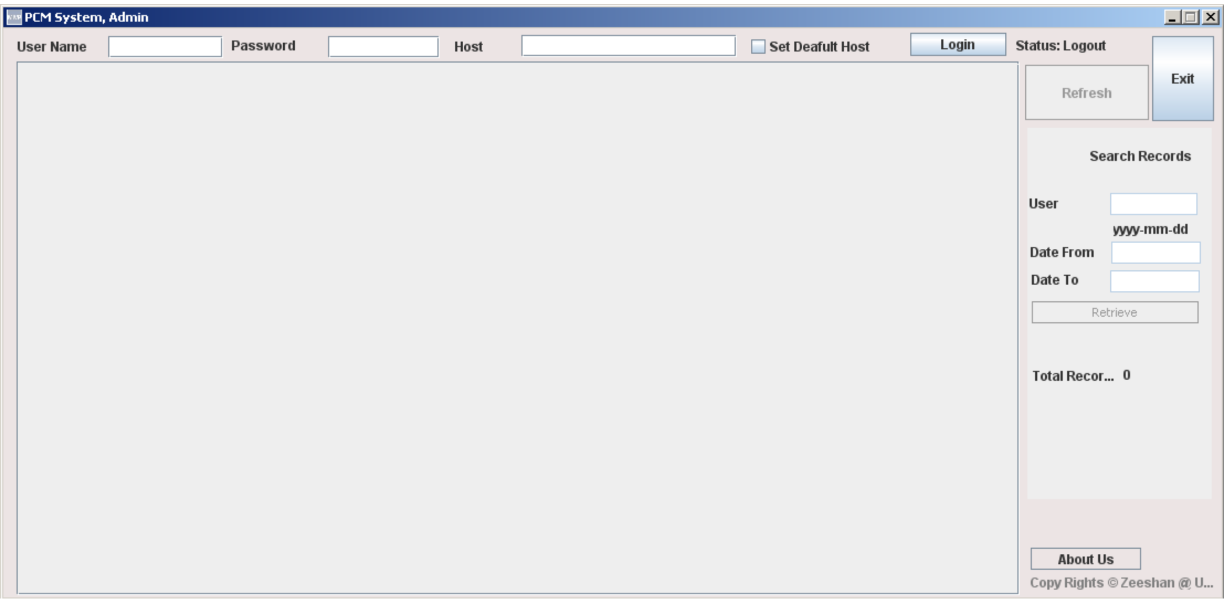


Figure Legend. It is the graphical user interface of the Admin module consisting of some feature: User name, Password, Host, Set default host, Login, Refresh, User, Date from, Date to, Retrieve, Total records and About us.

Figure 2. PCM System; Admin Module

3. PCM System UML Descriptions

The most direct method of designing architectures of software applications is Unified Modelling Language (UML), as it plays important role in standardizing way of designing by creating different abstract models. It is capable of facilitating software engineers with stand alone and interconnected semiformal (Meta) design views for modelling software architectures[13].

Here software designs are created using UML principles to have better understanding of PCM System in terms of its implementation, usage and working, Designed UML diagrams are describing over all feature based functionality, user accessibility, experimental data flow, internal system work flow, system sequence, involved component's integration and source code structure.

This manuscript presents following PCM System UML designs: *Use Case, Data Flow, Internal Work Flow, System Sequence, Class* and *Component Diagrams*.

3.1. Use Case

Use case is the specific textual and visual method of presenting software application's functionalities comprising all ways of user system interactions[14], consisting of two main symbolic notations i.e. Actor and Activities. In most of the cases actor is either user or system itself as a remote actor and activity is the event triggered by the system in response to the request by actor for some action. The designed use case diagram (Figure 3) of PCM System describes the user system interaction (Table 2) which consists of a *User (actor)*, four direct activities: *Login System, Open Document, Print Request* and *Printed Document*, and two indirect associated activities: *Printer/Plotter* and *Print Information*.

The use case of PCM System explains the basic flow of user system interaction starting with the execution of software application. User logins successfully, opens any text or graphic document (e.g. Microsoft word, power point, excel sheet, notepad, image file, PDF etc.) and send print request to the print server for printing. In return user will get printed document and print information status will be extracted and saved.

Table 2. PCM System; Use Case Description

Use Case	Details
Number	UC – 1
Application	PCM System
Description	This use case consists of a user (actor), four direct activities (Login System, Open Document, Print Request and Printed Document) and two indirect associated activities (Printer/Plotter and Print Information).
Primary Actor	User (Actor)
Precondition	Software application successfully running.
Trigger / Events	Login into System Open Document Send Print Request
Basic Flow	Basic flow consists of following steps: Start software application using Administrator rights. User login successfully. Open any text or graphic document (e.g. word application) Send print request to the print server for printing. In case of successful printing, get printed document. Print information saved by system.
Alternate Flows	Exception will be notified to the user.

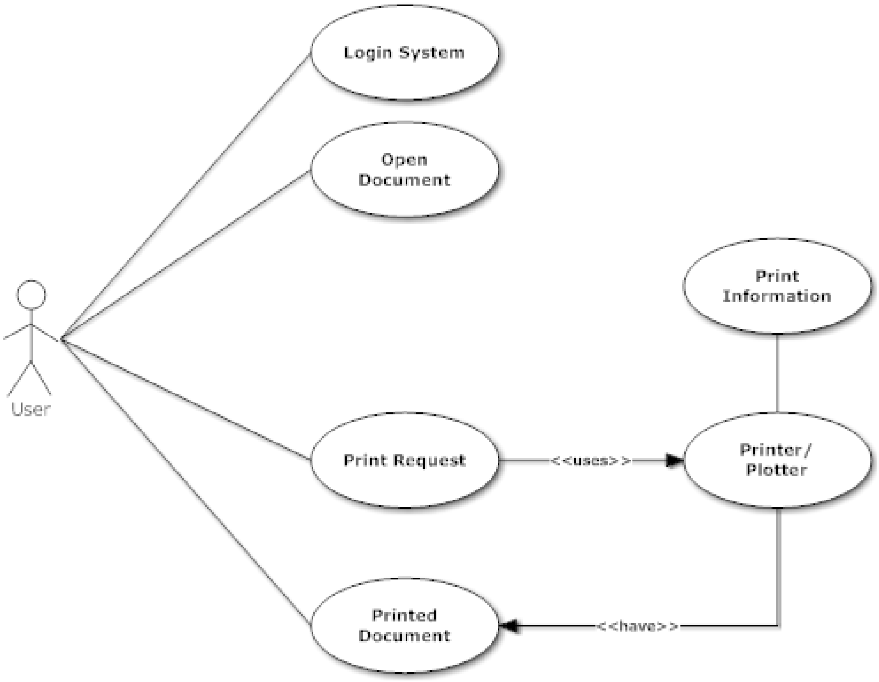


Figure Legend. It is the use case diagram of PCM System consisting of a User, five direct and four remote (indirect) activities

Figure 3. PCM System; Use Case

3.2. Data Flow Diagram

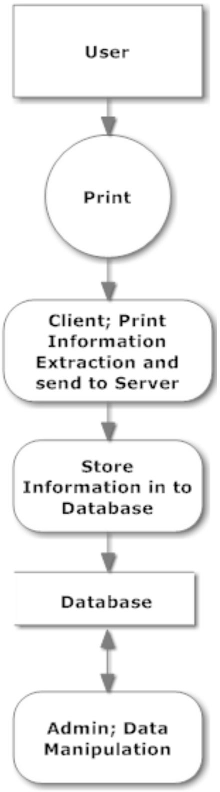

User
Print
Client; Print Information Extraction and send to Server
Store Information in to Database
Database
Admin; Data Manipulation

Figure Legend. It is the data flow diagram of PCM System consisting of a User, process i.e. Print, Print Information Extraction and send to server, Store information in to Database, a Database and Admin; Data Manipulation process.

Figure 4. PCM System; Data Flow Diagram

The data flow diagram is the way of producing visual presentation of data flow inside a software application[15]. This data flow diagram presents internal data flow of PCM System (Figure 4).

At first data file (text or graphic or both) is opened by the user and sent for printing. Print information is extracted and sent to the main server by the client module. The server module will then store received data in the database, which then can be manipulated by administrator using the admin module.

3.3. Flow Chart

Flow chart is the step by step visual representation of defined interlinked processes (operations) in a software application[16], categorized in different shaped boxes representing different kinds of operations connected by directional and unidirectional (associated) arrows.

The flow chart of PCM System starts with the user login in the system connected to the workgroup of the intranet. User is supposed to open (one or multiple) document file(s) and prepare request for the printing using plugged printers. In case of unsuccessful printing, control will be sent back to File and notification will be sent to the user. If printing will be successful then print information (data packets) will be sent to the main server of the work group. In case of unsuccessful data packet transfer control will be sent back to the client module and in case of successful data packet transfer information will be stored in the database (Figure 5) and system will be ready for next transaction.

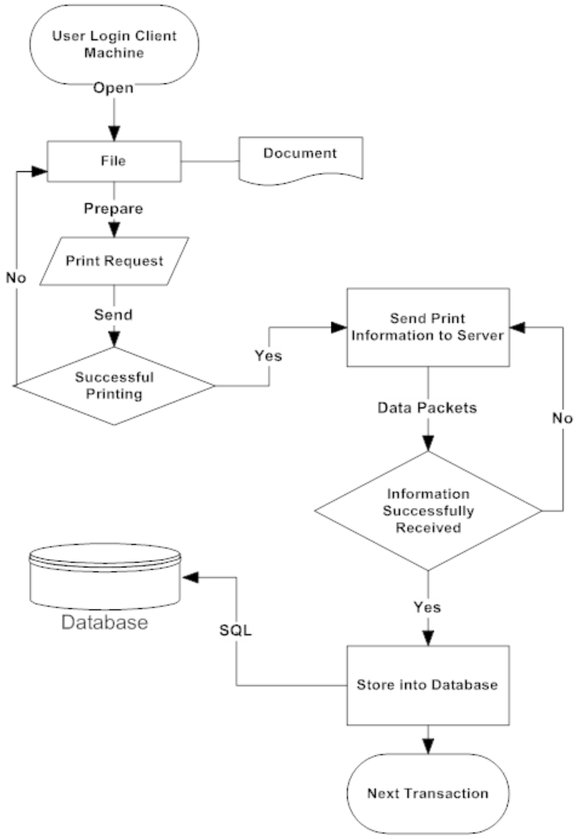


Figure Legend. It is the flow chart of PCM System consisting of user input, print process, and conditionally directed processes i.e. sending, receiving and saving data.

Figure 5. PCM System; Flow Chart

3.4. System Sequence Diagram

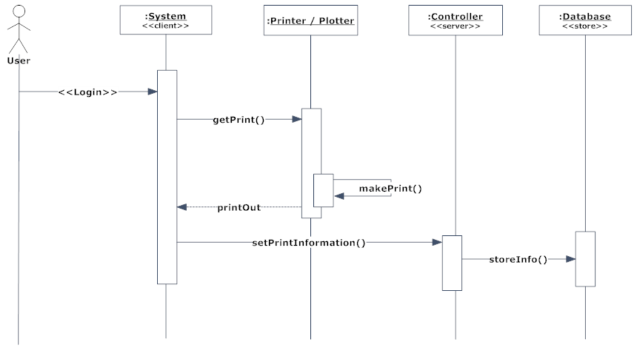


Figure Legend. It is the abstract system sequence diagram of PCM System consisting of four main steps (System, Printer/Plotter, Controller and Database) with several directing arrows in between.

Figure 6. PCM System; System Sequence Diagram

The system sequence diagram (SSD) represents a particular scenario (text or graphic) defined by the use case, especially for the transaction oriented systems[9]. SSD mainly consists of actors (users), messages (methods) called by the actors, return values (optional, if any) and loop indicators. The main reason of using SSD is to explore the logic of multifaceted operations (procedures or functions).

The SSD (Figure 6) of PCM System consists of four steps with individual but interlinked tasks: *System (client), Printer/Plotter, Controller (server)* and *Database (Store).* Step system starts with user login at a client based system of the workgroup and using method “getPrint()” sends request to the step Printer/Plotter, which then runs method “makePrint” for printing operation. Then calls method “printOut” and sends print results to the step system.

The step system then runs method “setPrintInformation” and sends print information to the step Controller, which then runs method “storeInfo” to send information in the step Database (to store).

3.5. Component Diagram

Component diagram is the visual presentation of assembled constituents representing structural relationship between service provider and consumer[10]. It allows the designer to confirm system's functionality to be implemented in the form of components using internal and third party services (e.g. programming languages, libraries, executables, application programming interfaces, frameworks etc.) in terms of nature and behaviour.

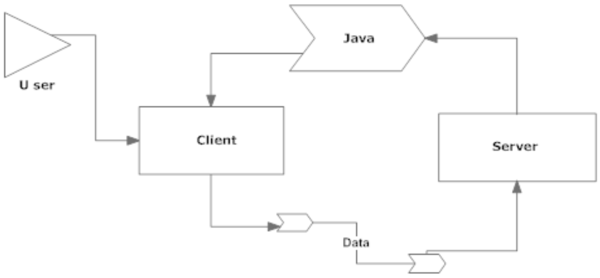


Figure Legend. It is the component diagram of PCM System consisting of a user, one platform component (Java) and two main components (Client and Server).

Figure 7. PCM System; Component Diagram

All the modules of proposed PCM System (including admin, server and client) are implemented in Java programming language using Eclipse editor. Internal intranet communication is based on sockets. Print lookup service is implemented for Print information extraction from user system. Relational database was created in MySQL enterprise database management system. (Figure 7)

3.6. Class Diagram

Class diagram is the static representation of relationships between defined classes for the development of a software application[11],[12]. The source code development of PCM System is divided into seven main classes (Figure 8) i.e. Client, Server, MainClass, Print_Admin,ResultSetCellRenderer, ResultSetTableModel and AboutUs.

1. Client is a multi attribute class with four methods: sendDatatoServer, buildData, startProcess and main, created in package PrintClient. “sendDatatoServer” is the method to connect and send data to server, “buildData” is the method to build data packets, “startProcess” start performing jobs and “main” executes client module.

2. Server is a multi attribute class with three methods: getData, storeData and main, , created in package PrintServer. “getData” is the method to receive data from client, “storeData” is the method to send data to database server to store and “main” executes client module.

3. Main is a single attribute class with one method “main” to execute Amdin module, created in package PrintAdmin.

4. Print_Admin is a multi attribute class with twenty four methods: initialize, getJContentPane, connectDatabase, disconnect, enableGUI, setEnglishGUI, getData, setData, get JText_Login_User_Name, get JButton_Login, get JText_Host, get JButton_AboutUs, get JPasswordField_Password, get JScrollPane_Data, get JTable_Data, getJButton_Refresh, get JPanel_Search, get JText_UserName, getJText_PrintDateTo, get JButton_RetreiveData, getJCheckBox_DefaultHost and get JButton_Exit, created in package PrintAdmin. “Initialize” initializes GUI components, “getJContentPane” initializes content pane component, “connectDatabase” establishes database connection, “disconnect” disengage established database connection, “enableGUI” enables or disables GUI, “setEnglishGUI” converts control text in German language, “getData” retrives result from database, “setData” sets record set, “getJText_Login_User_Name” initializes text control for user login information, “getJButton_Login” initializes login button, “getJText_Host” initializes text control for host information, “getJButton_AboutUs” initializes button for giving version information, “getJPasswordField_Password” initializes password text field, “getJScrollPane_Data” initializes scroll pane, “getJTable_Data” initializes table, “getJButton_Refresh” initializes button to refresh database connection, “getJPanel_Search” initializes search panel, “getJText_UserName” initializes user name text field, “getJText_PrintDateTo” initializes field to take date, “getJButton_RetreiveData” initializes button to retrieve searched data, “getJCheckBox_DefaultHost” initializes check box to set default host getJButton_Exit initializes exit button.

5. ResultSetCellRenderer is a multi attribute class with two methods: ResultSetCellRenderer and getTableCellRendererComponent. ResultSetCellRenderer is the constructor and getTableCellRendererComponent is the method to render components.

6. ResultSetTableModel is a multi attribute class with eight methods: ResultSetTableModel, close, getColumnCount, getRowCount, getColumnName, getColumnClass, getValueAt and isCellEditable, created in package PrintAdmin. "ResultSetTableModel" is the constructor creates a TableModel from a ResultSet, "close" closes the ResultSet, "getColumnCount" returns the number of columns in table, "getRowCount" returns the number of rows in table, "getColumnName" returns columns names from the ResultSetMetaData, "getColumnClass" specifies the data type for each column of table, "getValueAt" returns the value at each cell of the table and "isCellEditable" returns the status of table, whether it is editable or not.

7. AboutUs is a multi attribute class with four methods: AboutUs, Initialize, getJContentPane and getJButton, created in package PrintAdmin. "AboutUs" is the constructor, "initialize" sets the GUI, "getJContentPane" initializes content pane and "getJButton" initializes buttons.

4. PCM System Validation

PCM System was deployed in a medium sized departmental workgroup, intranet consisting of around 50 user systems. Briefly describing the network structure, user systems are interlinked with a main server system, a database server system and three printers via printer server system. The whole case study consists of following ten steps:

1. The database was created using SQL scripts and made available at database server of the workgroup. Then the Admin module was installed and executed in the administrator system of the workgroup. Administrator then connected PCM System’s admin module to the database server (with valid login name, password and host address).

2. The PCM System’s server module was installed and executed in the main server of the workgroup. When the server module started functioning, it immediately sent request to connect to the database server, and soon after successful connection it started looking for client requests.

3. The PCM System’s client module was installed and executed in all client systems of the workgroup. When the client module was executed, at first it snatched all information based on plugged printers (via print server): *Lexmark C734 XL, HP LaserJet 4250 PCL 6, HP LaserJet 4100 Series PCL, Adobe PDF, Microsoft Office Document Image Writer* and *Microsoft XPS Document Writer*. (Figure 9)

4. User “zea77ir” successfully logged-in a user system of the work group. Opened a document and sent a print request using printer “Adobe PDF”. (Figure 9)

5. The print information was immediately extracted and sent by the client module to the main server system (Figure 9), where server module was already running, waiting and ready to facilitate client request (Figure 10).

6. Client request for connection was received at server module sent by the client module and later after the successful authentication, server successfully received data packets.

7. Then server automatically organized and sent received print information to the database server for storage and maintenance.

8. Database server received print information and successfully updated relational database with new entry.

9. The PCM System’s Admin (Figure 11) module was already running at administrator machine, connected to the database server, and got the intimation of newly added information.

10. The last entry in the record list of Admin module was print request sent by the client module (Figure 9), received by server (Figure 10) and stored by database server.

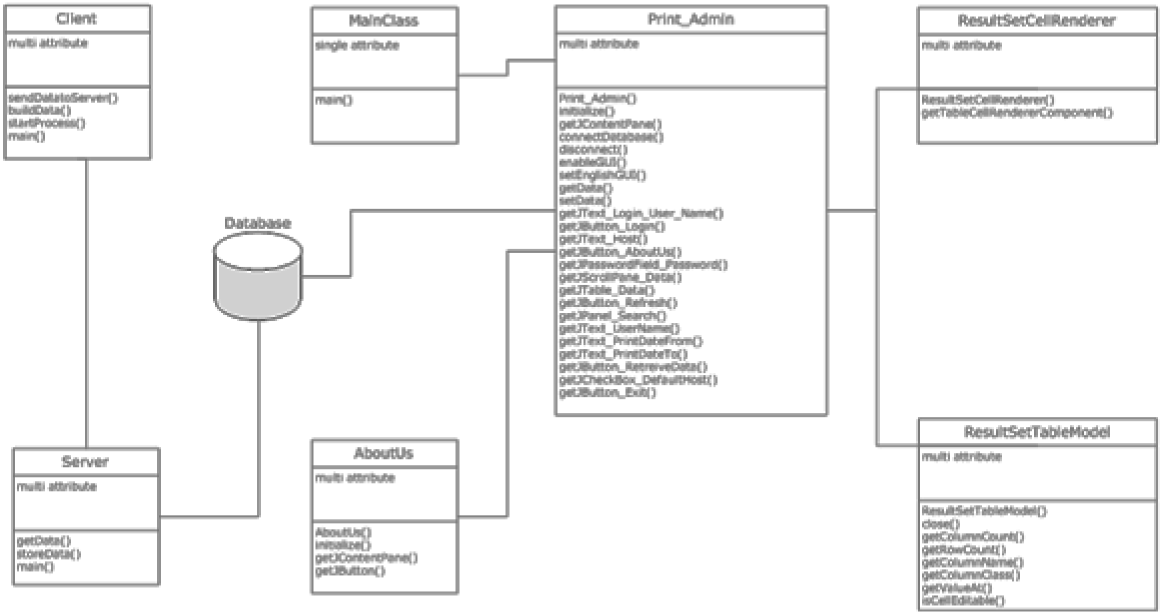
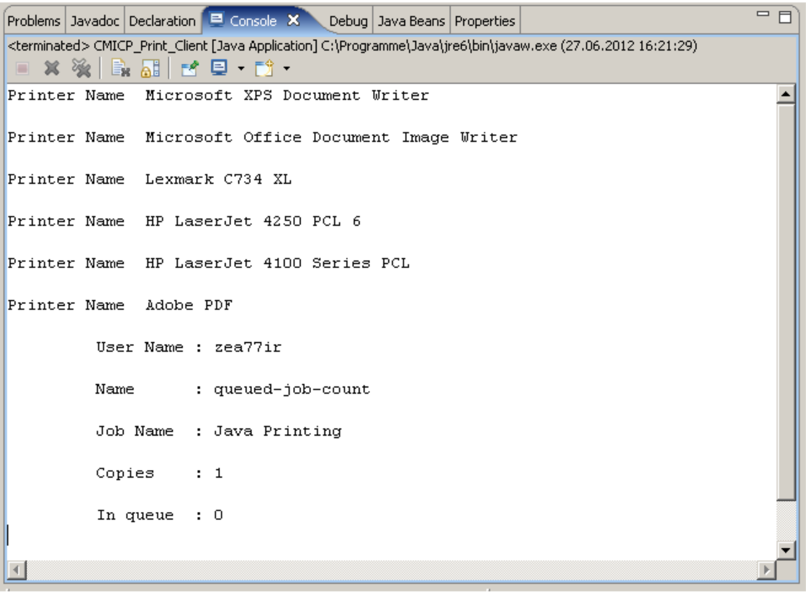


Figure Legend. It is the class diagram of PCM System consisting of six multi attribute classes: Client, Server, Print_Admin, ResultSetCellRenderer, ResultSetTableModel and AboutUs and one single attribute class: MainClass

Figure 8. PCM System; Class Diagram

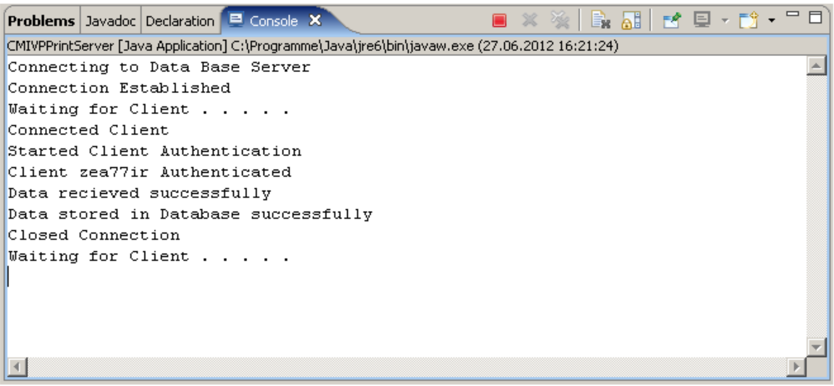


<terminated> CMICP_Print_Client [Java Application] C:\Programme\Java\jre6\bin\javaw.exe (27.06.2012 16:21:29)

```
Printer Name  Microsoft XPS Document Writer

Printer Name  Microsoft Office Document Image Writer

Printer Name  Lexmark C734 XL

Printer Name  HP LaserJet 4250 PCL 6

Printer Name  HP LaserJet 4100 Series PCL

Printer Name  Adobe PDF

         User Name : zea77ir

         Name      : queued-job-count

         Job Name  : Java Printing

         Copies    : 1

         In queue  : 0
```

Figure Legend. It is the running screen shot of executed client module of PCM System

Figure 9. PCM System; Client Module

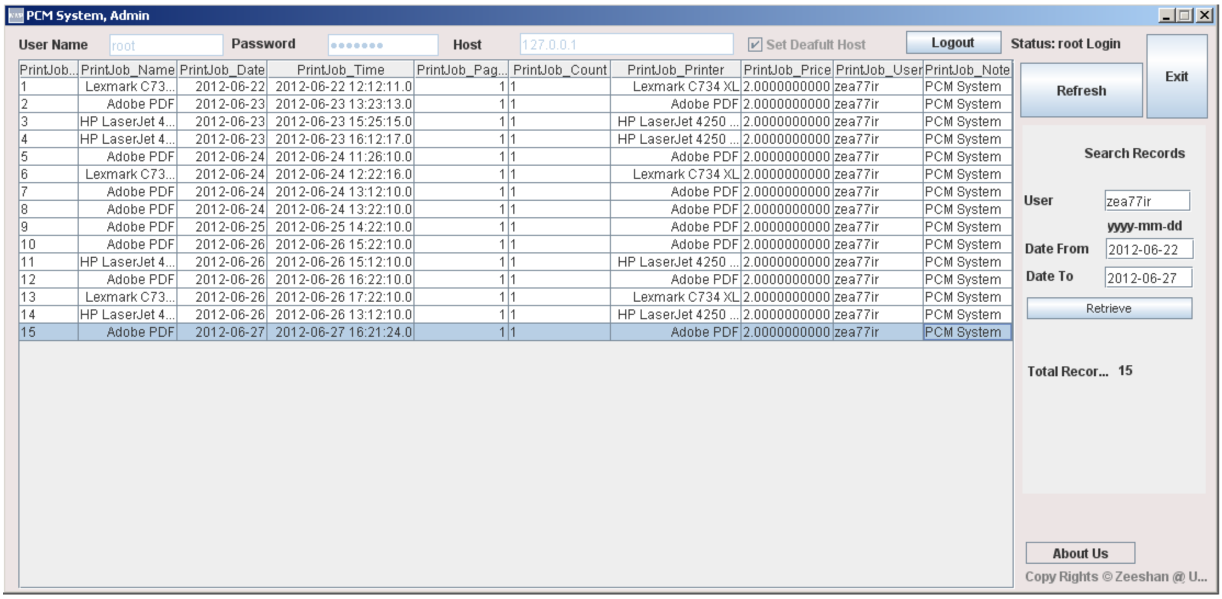


CMIVPPrintServer [Java Application] C:\Programme\Java\jre6\bin\javaw.exe (27.06.2012 16:21:24)

```
Connecting to Data Base Server
Connection Established
Waiting for Client . . . . .
Connected Client
Started Client Authentication
Client zea77ir Authenticated
Data recieved successfully
Data stored in Database successfully
Closed Connection
Waiting for Client . . . . .
```

Figure Legend. It is the running screen shot of executed server module of PCM System.

Figure 10. PCM System; Server Module



PCM System, Admin

User Name: root

Password: ●●●●●●●

Host: 127.0.0.1

☑ Set Deafult Host

Status: root Login

PrintJob...	PrintJob_Name	PrintJob_Date	PrintJob_Time	PrintJob_Pag...	PrintJob_Count	PrintJob_Printer	PrintJob_Price	PrintJob_User	PrintJob_Note
1	Lexmark C73...	2012-06-22	2012-06-22 12:12:11.0	1	1	Lexmark C734 XL	2.0000000000	zea77ir	PCM System
2	Adobe PDF	2012-06-23	2012-06-23 13:23:13.0	1	1	Adobe PDF	2.0000000000	zea77ir	PCM System
3	HP LaserJet 4...	2012-06-23	2012-06-23 15:25:15.0	1	1	HP LaserJet 4250 ...	2.0000000000	zea77ir	PCM System
4	HP LaserJet 4...	2012-06-23	2012-06-23 16:12:17.0	1	1	HP LaserJet 4250 ...	2.0000000000	zea77ir	PCM System
5	Adobe PDF	2012-06-24	2012-06-24 11:26:10.0	1	1	Adobe PDF	2.0000000000	zea77ir	PCM System
6	Lexmark C73...	2012-06-24	2012-06-24 12:22:16.0	1	1	Lexmark C734 XL	2.0000000000	zea77ir	PCM System
7	Adobe PDF	2012-06-24	2012-06-24 13:12:10.0	1	1	Adobe PDF	2.0000000000	zea77ir	PCM System
8	Adobe PDF	2012-06-24	2012-06-24 13:22:10.0	1	1	Adobe PDF	2.0000000000	zea77ir	PCM System
9	Adobe PDF	2012-06-25	2012-06-25 14:22:10.0	1	1	Adobe PDF	2.0000000000	zea77ir	PCM System
10	Adobe PDF	2012-06-26	2012-06-26 15:22:10.0	1	1	Adobe PDF	2.0000000000	zea77ir	PCM System
11	HP LaserJet 4...	2012-06-26	2012-06-26 15:12:10.0	1	1	HP LaserJet 4250 ...	2.0000000000	zea77ir	PCM System
12	Adobe PDF	2012-06-26	2012-06-26 16:22:10.0	1	1	Adobe PDF	2.0000000000	zea77ir	PCM System
13	Lexmark C73...	2012-06-26	2012-06-26 17:22:10.0	1	1	Lexmark C734 XL	2.0000000000	zea77ir	PCM System
14	HP LaserJet 4...	2012-06-26	2012-06-26 13:12:10.0	1	1	HP LaserJet 4250 ...	2.0000000000	zea77ir	PCM System
15	Adobe PDF	2012-06-27	2012-06-27 16:21:24.0	1	1	Adobe PDF	2.0000000000	zea77ir	PCM System

Search Records

User: zea77ir

yyyy-mm-dd

Date From: 2012-06-22

Date To: 2012-06-27

Total Recor... 15

Copy Rights © Zeeshan @ U...

Figure Legend. It is the running screen shot of executed admin module of PCM System

Figure 11. PCM System; Admin Module

5. Conclusions

This manuscript has presented research being conducted in the fields of system, embedded and network programming. To give technical reader a complete idea about software application, presented major implemented UML designs.

To familiarize user with software application, the graphical user interfaces of proposed software application has briefly described.

In the end of the manuscript, successfully validating PCM System in a ten stepped processes, presented a case study as well.

In future, enhancing this research and development work, an online user friendly web interface can also be developed which can provide access to the database using World Wide Web[27][28]. In addition to take advantage in extracting information efficiently, a natural language based search engine can also be developed or used (some existing)[29],[30],[31].

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