Appendix- ‘E’. Tools and Techniques Used

1. Java Agent Development Framework

Java Agent Development Framework (JADE) is a software framework fully implemented in Java language. It is developed by Telecom Italia Laboratory and freely available. It simplifies the implementation of multi-agent systems as a middleware. JADE is FIPA (Foundation of Intelligent Physical Agent) compliant tool. The agents developed using JADE can be distributed across machines. The machines may have different operating systems. It includes:

- A runtime environment where JADE agents can “live” and that must be active on a given host.
- A library of classes that programmers have to/can use (directly or by specializing them) to develop their agents.
- A suite of graphical tools that allows administration and monitoring the activities of running agents.

Agents of MASRAM (Multi-agent System for Resource Allocation and Monitoring) have been implemented using JADE 3.7. The classes provided by JADE are imported and inherited in Java programs to build agents. The classes like `jade.core.Agent`, `jade.code.AID` and `jade.lang.ACL` are most widely used. The inherited java program has one startup method as `setup()`. All the tasks to be performed by agents are implemented in this method. Agent class also provides methods to implement behavior of the agents. The three agents are implemented with Agent class and ACL (Agent Communication Language) class. Using ACL, agents communicate with each other.

2. Java 2 Enterprise Edition

Main components of Java 2 Enterprise Edition (J2EE) are:

a. Java Server Pages

Java Server Pages (JSP) is a technology based on the Java language and enables the development of Dynamic Web Sites. JSP was developed by Sun Microsystems to
allow server side development. JSP files are HTML (Hypertext Markup Language) files with special Tags containing Java source code that provides the dynamic contents. JSP source code runs on the web server in the JSP Servlet Engine. Apache Tomcat 6.0 is used to run JSP programs. The JSP Servlet engine dynamically generates the HTML and sends the HTML output to the client’s web browser. Main reasons to use JSP:

- Multi platform
- Component reuse by using JavaBeans
- Advantages of Java.
- Platform independence.

In research work, JSP is used to implement presentation layer of web-based MASRAM. The users of the system interact with agents using presentation layer. Combination of JSP and HTML control helped in developing interfaces to input data and to show results.

b. Java

Java is a pure Object Oriented Programming Language created by James Gosling of Sun Microsystems in 1991. The first public available version of Java (Java 1.0) was released in 1995. Over the period, several versions of Java were released which enhanced the language and its libraries. Java is platform independent language. It compiles the source program and converts into byte-code, which is understandable to Java Virtual Machine (JVM). The main characteristics are briefed below:

- **Platform Independent**: Java programs use the Java virtual machine as abstraction and do not access the operating system directly. This makes Java programs highly portable. A Java program which is standard complaint and follows certain rules can run unmodified at platforms like Windows and Linux.

- **Object-Orientated Programming Language**: Except the primitive data types like int and float, all elements in Java are objects like String. It is pure object oriented as main function is written in class.

- **Strongly-typed Programming Language**: Java is strongly-typed, e.g. the types of the used variables must be pre-defined and conversion to other objects is relatively strict.
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- **Interpreted and Compiled Language**: Java source code is transferred into bytecode which does not depend on the target platform. This bytecode is interpreted by the Java Virtual machine (JVM). The JVM contains so called Hotspot-Compiler which translates critical bytecode into native code.

- **Automatic Memory Management**: Java manages the memory allocation and de-allocation for creating new objects. The program does not have direct access to the memory. The so-called garbage collector deletes automatically objects to which no active pointer exists.

  Java 1.6 is used with JADE to develop our system. The core Java is used at different stages of development. During presentation layer, it is used with JSP, during Agent Layer, it inherits Agent class and during Database Layer implementation, it is used with JDBC (Java Database Connectivity) to interact with database.

c. **Java Database Connectivity (JDBC)**

There are many industrial oriented DBMSs like Oracle and DB2 which are commercially available. Each database has its own language and architecture. To convert application written in one database to another, one needs to rewrite the code. With JDBC, this barrier is overcome. Java can be connected to any database using JDBC provided driver is available on the machine. The process of connecting Java with database is divided into six steps:

- Loading JDBC Driver
- Establishing Connection
- Creating and Executing Statement
- Data Processing
- Return Result set
- Closing Connection.

In MASRAM, Oracle 9i is used at backend to support agents. The connection with database is established using JDBC. The package `java.sql` is used to perform operations like inserting data or retrieving data.
d. Java Beans

Java Beans are a reusable software component that can be visually manipulated in builder tools. Java bean consists of specifications and APIs for developing reusable server side components. Beans run on server. Beans plays important role in MASRAM to read/write contents for agent. One agent writes content for other using bean and other agent reads the same with help of common Ontology.

e. Java Servlet

A Java Servlet is a server-side program and is called by user interface. Servlets generally contain business logic to process a request. The output of the Servlet is sent back to the calling program and browser at the client side handles output and displays results to the user.

3. Oracle 9i

Oracle is an Object Relational Database Management System (ORDBMS). Data is stored as objects. The object type has three components: name, attributes and methods. Oracle creates tables based on user defined types and rows of which are called objects. Each row in Oracle table is given unique identification number called OID (Object Identification number). Oracle supports agents of the system and has the ability of creating nested tables. This reduces the 1:M relationship between tables of RDBMS. A column of ORDBMS table is made a type of nested table. This facility is used in designing the database. View is logical view of oracle tables. No data is stored in a view. A view pulls data based on query specified at the time of view creation. Oracle also provides features to write stored procedures/functions and packages. These are used in MASRAM to implement actions of agents. The code is written using PL/SQL (Procedural Language/ Structured Query Language).

The key features are:-

- Client/Server Environments (Distributed Processing)
- Large Databases and Space Management
- Many Concurrent Database Users
- High Transaction Processing Performance
- High Transaction Processing Performance
4. Web Service Integration Gateway

Web Service Integration Gateway (WSIG) provides support for invocation of JADE agent services from web service clients. It consists of WSDL (Web Service Definition Language) for service descriptions, SOAP (Simple Object Access Protocol) message transport and a UDDI (Universal Description Discovery and Integration) repository for publishing Web services.

- WSIG Servlet
- WSIG Agent

The WSIG Servlet is used as the front-end in the Internet world and is responsible for:

- Serving incoming HTTP (Hypertext Transfer Protocol) / SOAP requests
- Extracting the SOAP message
- Preparing the corresponding agent action and passing it to the WSIG Agent
- Converting the action result into a SOAP message
- Preparing the HTTP / SOAP response to be sent back to the client.

The WSIG Agent is the gateway between the Web and the Agent’s world and is responsible for:

- Forwarding agent actions received from the WSIG Servlet to the agents actually able to serve them and getting back responses.
- Subscribing to the JADE DF (Directory Facilitator) to receive notifications about Agent Registrations/Deregistration.
Creating the WSDL corresponding to each agent service registered with the DF and publishing the service in a UDDI registry if needed.

Two main processes are continuously active in the WSIG web application:

- The process responsible for intercepting DF registrations/deregistration and converting them into suitable WSDLs. As mentioned, this process is completely carried out by the WSIG Agent.
- The process responsible for serving incoming web service requests and triggering the corresponding agent actions. The WSIG Servlet (performing the necessary translations) and the WSIG Agent (forwarding requests to agents able to serve them) carry out this process jointly.

5. **Microsoft Visio**

Microsoft Visio (MS-Visio) is a graphical tool used to draw wide range of diagrams including, flowcharts, organization charts, scale, floor plans, network diagrams and many other diagrams. MS-Visio helps IT (Information Technology) and Business Professionals to visualize, explore and communicate complex information. Visio, apart from static diagrams, creates database-connected diagrams. Using MS-Visio diagrams, current state of key processes, resources and system can be visualized easily. The key features are as described below.

- Quick access to template
- Connect shapes without drawing connectors
- Links data to shapes
- Displays data interactively in diagrams
- Refreshing data
- Visualizing and exploring business data
- Generation of reports
- Professional looking diagrams
- Support for UML diagrams.

Since, MS-Visio supports UML (Unified Modeling Language), so it is used in MASRAM to model and design the system. The diagrams are drawn as per AUML (Agent Unified Modeling Language) standard using MS-Visio.
6. Analytic Hierarchy Process (AHP)

AHP proposed by Saaty is a very popular technique used in Multi Criteria Decision-Making involving non-quantitative data. It has been in use in many decision-making problems. It uses pairwise comparisons. Pairwise comparison was introduced in 1870 but developed in 1927. In this technique, a square matrix of size $n$ based on pairwise comparison is developed where $n$ is the number of alternatives. Pairwise comparison is done in such a way that if $i^{th}$ alternative is twice as good as $j^{th}$ alternative, $j^{th}$ alternative is $\frac{1}{2}$ times better than $i^{th}$ alternative. It uses relative scale to quantify non-quantitative data. One such common scale is given below.

<table>
<thead>
<tr>
<th>Importance</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal important</td>
</tr>
<tr>
<td>3</td>
<td>Someone more important</td>
</tr>
<tr>
<td>5</td>
<td>Much more important</td>
</tr>
<tr>
<td>7</td>
<td>Very much more important</td>
</tr>
<tr>
<td>9</td>
<td>Absolutely more important</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values</td>
</tr>
</tbody>
</table>

Decision-makers are asked to give relative importance to one over the other and after assigning a relative value, a pairwise comparison matrix is generated. Next step is to evaluate relative weight or importance using Eigenvector corresponding to each alternative. The last step is to measure Consistency Ratio (CR) to know how consistent judgments have been. If CR is between 0 and 0.1, judgment is worthy, otherwise it is unworthy. AHP is used to compile the data collected from experts in the area of resource allocation and monitoring. The decision-making factors are relatively compared with each other and relative scale of each of twelve decision-making factors is calculated. It is also used in comparing proposals during evaluation phase.

7. Tomcat Apache

Tomcat Apache is an open source and freely available web server to execute JSP and Java Servlet based applications. It implements JSP 2.1 and Servlet 2.5 specifications. It is used to develop and deploy web applications. It runs on default port number 8080. This tool is available for both Windows and Linux platforms. Apache Tomcat also contains a HTTP connector that can be used to serve static HTML pages. The standard directory that is served
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by Apache Tomcat is below the Tomcat installation directory "webapps/ROOT". Static contents and JSP programs are kept under this directory.

8. MATLAB

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB, technical computing problems can be solved faster than with traditional programming languages such as C, C++ and FORTRAN. MATLAB was created by Cleve Moler and stands for Matrix Laboratory. It is originally used for Matrix theory, algebra and numerical analysis. MATLAB is used in wide range of applications including Signal and Image Processing, Communications, Control Design, Test and Measurement, Financial Modeling and Analysis, and Computational Biology. Add-on toolboxes (collections of special-purpose MATLAB functions available separately) extend the MATLAB environment to solve particular classes of problems in these application areas.

MATLAB provides a number of features for documenting and sharing the work. It allows integration of MATLAB code with other languages and applications and distributes MATLAB algorithms and applications. Its features include:

- High-level language for technical computing
- Development environment for managing code, files, and data
- Interactive tools for iterative exploration, design, and problem solving
- Mathematical functions for Linear Algebra, Statistics, Fourier Analysis, Filtering, Optimization, and Numerical Integration
- 2-D and 3-D graphics functions for visualizing data
- Tools for building custom Graphical User Interfaces
- Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, Java™, COM, and Microsoft® Excel

MATLAB is used in research work to implement AHP for calculating weights.

9. Agent Unified Modeling Language (AUML)

Unified Modeling Language (UML) was widely used for modeling and designing Object Oriented Systems. However, it is not fully suitable for modeling and designing Agent-based systems due to basic differences in Object Oriented Systems and Multi-agent
based Systems. Objects are reactive whereas agents are proactive and social. To fill the gap, FIPA (Foundation for Intelligent Physical Agents) started developing Agent Unified Modeling Language (AUML) to model and design Multi-agent based Systems. It supports the specifications of agents, interaction between them and communications. A three-layered approach is followed in depicting agent-based system using AUML. In the first layer, it uses packages and templates to represent the entire protocol. In second layer, it uses sequence, collaboration, activity and state-transition diagrams and in last layer, activity and state-transition diagrams are used to capture the internal behavior of the agents.