Knowledge Management Application of Internet of Things in Construction Waste Logistics with RFID Technology

[1]Lizong Zhang, [2]Anthony S. Atkins, [3]Hongnian Yu
[1, 2, 3]Faculty of CET, Staffordshire University,Octagon, Beaconside, Stafford ST18 0AD, United Kingdom
[1]l.zhang@staffs.ac.uk, [2]a.s.atkins@staffs.ac.uk, [3]h.yu@staffs.ac.uk

***Abstract*—The Internet of Things (IoT) is an emerging concept and that is currently under creation and development. However, it has already made an impact on many research domains by providing new solutions and ideas particularly in waste management and recycling. The IoT concept has provided a new research path that is conducive with public awareness of environmental protection considerations and improving recycling rates. This paper focuses on plasterboard waste as an example to propose a smart waste management framework. The 3 layers of the IoT model has been extended to 4-layers by splitting the application layer into knowledge management and visualization layer respectively. A smart waste management application has been developed, based on a case study of a local SME waste recycling company. This smart waste management system uses a service science approach, and it not only provides full logistical records for waste transportation but also provides waste collection arrangements and incident handling guidance to both management and operational staff.**

Keywords*—Knowledge Management Systems, RFID Technology, Plasterboard Waste, Smart Waste Management, Internet of Things, Service Science.

I. INTRODUCTION

The Internet of Things (IoT) is a emerge concept that was first proposed by Kevin Ashton in 1999 to describe an emerging global, Internet-based information service architecture [1]. This concept is currently under development, and there is no generally accepted definition, but IoT is receiving considerable attention and influences virtually all areas of academic and business, and waste disposal is no exception to the Internet of Things.

Waste management and recycling has become an issue, which is being addressed by both developed and developing countries. Inappropriate handling may result in serious environment concerns, or even disasters. Some waste which appears to be safe may release harmful components if not treated correctly, and plasterboard waste is an example as mixing it with domestic waste in landfill sites can result in H2S gas being emitted.

Regulation introduced in November 2008 prevents plasterboard waste being landfill with normal waste. It has to be treated as 'high gypsum waste' and disposed of in special mono cell designed landfill sites, which results in a significantly higher disposal cost. Currently DEFRA (Department for Environment Food and Rural Affairs) indicates that less than 10% of plasterboard waste is being recycled in the UK[2]. A target has been set by the Waste Framework Directive that aims to recover at least 70% of construction and demolition waste by 2020 [3]. Currently, there are only 4 recycling facilities available, which results in transportation issues and this is a barrier for increasing recycling. Consequently a solution for improving recycling rates is currently being sought by both government and environmental pressure groups.

An achievable solution to waste disposal is provided by the concept of 'Internet of Things'. In generally, the basic idea of IoT is enabling smart environments to recognize and identify objects, and retrieve information from the Internet to facilitate their adaptive functionality [1]. Based on the understanding of IoT and plasterboard waste management issues, a solution is proposed in this paper for auditing and tracking plasterboard waste and providing real-time instruction and job scheduling for operating staff using RFID technology and rule-based knowledge management technology. This 'Smart Waste Management System' undoubtedly could help to prevent fly-tipping and illegal disposal of waste, and result in improved recycling rates in the UK.

II. INTERNET OF THINGS AND SMART WASTE MANAGEMENT

There are many different definitions of the 'Internet of Things' proposed by different organisations and countries. The EU, China, Korea, USA and Japan are the main supporters and promoters of IoT, but there are many different names given to this concept, for example: 'Sensation China'- China, 'Smart Earth'- USA, 'U-Korean'- Korea and "Ubiquitous Computing" – Japan, etc. All of these research entities propose their own definition of IoT, and also the architectures in their project, which governments are funding in their respective countries. Consequently, the definition and architectures they propose are mostly 'localized' to match the demands of their respective societies and investment expenditures.

In Europe, there are about 8 different research groups on the IoT. All of them are integrated under the umbrella of the European Research Cluster on the Internet of Things (IERC) funded by the European 'Seventh Framework Programme'. These groups are working together and focus on different aspects of IoT, with the aim of building an acceptable IoT prototype by 2020 [4].

A definition of 'Internet of Things' proposed by CASAGRAS2, a research group under the IERC is 'a global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object-identification, sensor and connection capability as the basis for the development of independent federated services and applications. These will be characterised by a high degree of autonomous data capture, event transfer, network connectivity and interoperability'. [5].

Comparison of definitions from other regions of the world shows the concept is similar but is expressed in different ways. For example, in China, the IoT is receiving considerable attention compared with other countries because the Chinese Premier Jiabao Wen visited the Wuxi IoTcentre in August 2009 and initiated the launch of a new project 'Sensing China'[6]. The Chinese government's official definition of the 'Internet of Things' is 'expanding application and network extension of communication network and internet, it uses sensor technology and intelligence device in perception of the physical world, and communication, computing, process mining and knowledge via network, realising the information exchange and seamless connection between 'people and things' or 'things and things', and result in real-time control, management and decision making to the physical world.'[7]

The two definitions mentioned concern the key concepts in IoT: identifying objects, data capture/mining, network and applications. Consequently, the general idea is similar and it can be concluded as: making the physical world object recognisable by the network and enabling exchange of information itself. The network could provide some function to control or manage the physical world. In addition, the architectures from the different research group are similar, even if these are different in detail, and the outlined structure can be described in a three layer model: the sensing layer, network layer and application layer respectively [8].

Plasterboard waste management is an application area that could adopt the IoT to improve the recycling rate. Based on the understanding of IoT and the waste management issues, a 'Smart Waste Management System' with a 4-layer structure is proposed, which follows the IoT three model but is extended to adopt knowledge management technology and visualisation 'localised' for the construction industry.

III. The 4-Layers System Architecture

The 4-layer structure is an extension of the three layer model of 'Internet of Things', which is illustrated in Fig. 1. This structure consists of 'Data Acquiring' layer, 'Data Integration' layer, 'Knowledge Management' layer and 'Visualization' layer respectively. The two main technologies adopted in this framework are the RFID technology and knowledge management technology[9].

The first layer is referred to as the 'Data Acquiring' layer which represents the sensing layer in IoT three layer model. This layer is the route for acquiring the data and information about the physical world; it mainly relies on the RFID technology. In the waste management scenario, the 'objects' referred to the IoT model are the waste or vehicles with the identifying function attachment. In this framework, RFID is an ideal solution because it can provide a low cost tracking and tracing system for contaminated waste in the construction industry. The proposed use of passive RFID tags provides adequate read range using low price (<5p) passive tags for monitoring waste container movement. As the vehicle or waste containers are RFID tagged, they then became the 'Objects' in IoT that could be recognized by the system[10].

The data captured in the Data Acquiring layer is not only from the RFID technology, but also from other sources, such as human input data and online weather reports etc. This 'raw' data only has meaning in its domain, for example, RFID data by itself is meaningless unless it is classified and linked to some 'object' and the information contextualised such as a tagged vehicle enter a recycling site at specific date and time etc. The lowest layer is only responsible for collecting data and the different sources in this layer are virtually independent.

Integrating data from the 'Data Acquiring' layer to provide information is the aspect of 'Data Integrating', which is located in the second layer. This layer can be referred to as the 'Network' layer in IoT model which has more functionality. It is not only responsible for 'network' but also for 'data storage'. The data from the different sources are stored in the database within organised positions where the next layer could request this information[11].

The 'Data Integrating' layer stores the data individually from the lowest layer and then links them by extracting the important parts to store in the central database. The information stored in the central database is a combination of all data sources and will be used as 'fact' for the next layer of knowledge management. For example, waste ID, waste type, weather conditions, time packed and comments from operational staff, will be stored together.

The third layer is the 'Knowledge Management' layer, which is responsible for generating logistical and tracking support including collection arrangements, incident solutions and also providing guidance for operational staff. This feature is supported by the adopted rule-based knowledge management technology, based on information and data from the lower layer. It processes this information and sends the reasoning result to the upper layer[11].

The Rule-based Knowledge Management system is the major part of this layer. This layer contains two main components: the knowledge base, which is used for storing domain knowledge in production rule format; and the fact base, which stores the current situation that equates to the central database in the lower layer. The core of this layer is a reasoning engine that can apply the domain knowledge to the current situation and then generate an acceptable result.

The results need to be translated to human readable text or diagrams, this is the requirement of the highest 'Visualization' layer[11]. The first important feature is the explanation, provided by the 'explanation mechanism' of the Knowledge Management System. This is responsible for explaining the result to the user and also the reasoning procedure required. In general, the features of this layer are translating the results and displaying on a terminal. However, the type of terminal can vary and could include computer, mobile phone, PDA or special designed terminal. The display media could be short message, web pages and/or client program. Consequently the display on the target client/terminal device is another feather of this layer. The third feature of this layer is the communication function between the users and system, with all users' commands and operations of the system going through this layer.

The Knowledge Management Layer and Visualization Layer correspond to the Application Layer in the IoT model, where it is the main feature to achieve the system functionality. The lowest two layers are only for data collection, storage and management. Therefore, in this 4-layer framework, the upper two layers can be changed or modified to match different application and domain areas.

IV. Structure Of Smart Plasterboard Waste Management System

The data collection technology mainly relies on RFID technology, which is an automatic identification technology and the successor to barcode systems for providing identity of objects. It can be applied in asset tracking, access control and security aspects etc.

In the smart plasterboard waste management system, RFID plays two key roles: firstly, the object identification, and secondly, location information provider. The reason for choosing RFID as the data collection technology is mainly based on low price and the application environment. The passive RFID system that is used in the prototype provides a cheap tag costing about less than 5p and it could be cheaper if larger volume (>1000) are purchased. The low price enables the disposable feature of the tags, which can be applied to individual waste bags for either recycling or disposal of the waste. The RFID system can overcome the difficulties of barcode and/or written identification systems as it is less prone to contamination from the waste and/or weather conditions.

The system structure is illustrated in Fig. 2, which is developed for a refurbishment and/or demolition site scenario. The RIFD tags could be attached to each bag of waste and the key 'gates' are installed with RFID readers. The system can then collect the movement data of any waste container and a central server would store the data for use in the knowledge management system.

V. THE KNOWLEDGE MANAGEMENT SYSTEM

There are two main features of the smart waste management system: firstly it generates the waste collection arrangement which is based on the company's contracts and previous collection records. The second is to help the operating staff deal with the waste including normal guidance and incident handling. To achieve these features, knowledge management technology has to be adopted into the system.

Rule-base Knowledge Management technology is introduced as the key part for applying the intelligence functions to the system by reasoning the fact data along with the rules. Fig. 3 is a technology view of the system, which illustrates and focuses on the knowledge management system.

There are three databases to support the knowledge management function, two of them have been described in Section III. the 'Records' database is the central database in the framework, and stores the logistic records together with the reasoning results; The 'Rule' database is refer to as the knowledge base. Another database, called the 'Fact' Database, stores the variables and parameters that are acquired from the 'Records Database', and are used in the reasoning procedures.

The knowledge management system includes two other important components, the 'Reasoning Engine' and the 'Explanation Mechanism'. The 'Reasoning Engine' is the most important part that controls the progress of reasoning, and finally generates 'reasonable' results. The result is then passed to 'Explanation Mechanism' before it is displayed to the users. The 'Explanation Mechanism' is responsible for translating the data/code format result to human readable information, and it is located in the visualisation layer of the framework.

Fig.. 4, Reasoning Procedure[12]

VI. The Reasoning Procedure

The Knowledge management reasoning procedure is started by data changes in the fact base. This is called 'Data Driven' Reasoning or 'Forward Chain' Reasoning. The fact base stores all the parameters and variables used in the conditions. The conditions are undoubtedly a part of a rule. Consequently, any change of data in the fact database will trigger a rule to start verification or fire. There is an exception in that some variables are used only to store the outcomes of the rules, and not linked to any condition.

Fig. 4 shows the general reasoning procedure. The first trigger of reasoning normally starts from the main system kernel when it finds the need for reasoning. Once the system determines the need for reasoning, it will update parameters that relate to the current situation to the fact database. The update action must go through the Knowledge Management System and thus can be monitored and a reasoning cycle is triggered. A typical example is when an unexpected record is found or the time is due for planning the next period of a collection schedule.

Fig. 5 illustrates further details concerning the reasoning procedure. After the initial updating is completed by the system, the following reasoning procedure is then controlled by the Knowledge Management system. The updated fact can be addressed by the reasoning engine and the conditions containing this fact will be determined. The next step is finding out the rules that are affected by these conditions, then the rules are verified and false rules are discarded and only valid rules are passed to the next step. The ideal situation is that only one rule has been left to be fired, but usually multiple rules are still present. Therefore, a conflict resolution method has to be applied to ensure that only one rule can be fired. In general, the fired rule will generate some facts and their value will be updated into the fact base, and the update action will trigger the next turn of reasoning until there is no rule to fire or no fact to be updated. The final status of the records in the fact base is consider as the result and will be passed to explanation mechanism with the reasoning procedure records to be translated to user readable information.

VII. The Conflict Resolution Strategy

Three strategies for solving rule confliction are introduced to the prototype system: the longest match strategy, simple priority strategy, and certainly factor respectively. The three strategies are introduced to ensure that only one rule can be fired in each cycle and only one can be activated at the same time in a reasoning cycle.

The first method is the longest match strategy which aims to find the reasoning path that contains the most conditions. In this strategy, the reasoning engine will try every possible path of the reasoning chain, but only chose the path which has the most conditions as the final path, and passes the result as the final goal. Therefore, the reasoning engine needs to spend time trying those paths and also needs to create temporary records for these results, and consequently, the speed is slower than the simple priority strategy.

The simple priority strategy is the fastest as it does not need to try all the paths but only compares the priority in the current stage. In this strategy, each rule has been assigned a 'priority' value, which is an attribute of the rules and assigned when the rule base is built. Once conflict happens, the highest one will be fired, and others will just simply be ignored. If the priority is the same or there are two valid rules, then the first rule will be fired.

The third method is the 'Certainly Factor' (CF), which is a concept from uncertainly reasoning. The Certainly Factor is an extra attribute that is assigned to the facts represents the 'level of believes'. The reasoning engine will fire all match rules in one cycle and each result will be stored in the fact database with the CF. After the reasoning cycle is completed the output is not a simple conclusion that has multiple possible situations/results with it's certainly factor built into it, but the system will intentionally choose the highest CF, or display all the result for users' query and judgment.

VIII. Demostration For An Example Scenario

A prototype application was developed based on an SME waste recycling company. The company is a local waste recycling company that has about 30 vehicles including skips, trucks and vans etc. It recycles most types of waste from the local area, including wood, metals, cardboard, construction and also plasterboard waste. This company allocates vehicles to pick up waste from contracted sites and deliver to their recycling centre. Two members of staff are engaged in arranging the collection schedule on a manual daily basis, usually the day before, and the schedules are distributed to the operating staff and drivers at the start of their shift. The order of site scheduling is random and determined by the drivers based on their personal experience.

This procedure initially worked satisfactory in the past but with increased growth it is experiencing difficulties. The sites schedule is amended sometimes due to major regular customers requesting urgent pickups and/or additional empty waste container deliveries to site resulting in some customers being delayed by a day.

This case study scenario uses approximately 30 vehicles and 30 sites including the depot and recycling centre together with a plasterboard manufacturer which is also considered as a site because it's the final destination of the recycled product[11]. The system was developed based on this company's requirements focusing on automatic collection schedules for the drivers together with operational staff instructions. The system also includes additional features for audit and monitoring the tonnage of plasterboard waste movement, which could be used for verification of waste treatments and landfill for public scrutiny and government authentication.

Fig. 6 illustrates the Knowledge Management System interface, which shows the reasoning procedure and the final report. Fig. 6a is debug interface which displays the reasoning procedure in detail; and each step is listed with corresponding explanation. Fig. 6b is a concise report to indicate the current stages and reminders of any missing information.

The reasoning explanation report explains the system decisions, and is outlined in Fig. 6c: 'Tonnage more than 5000KG, loose packed, assign a Type 3 Vehicle'. It also shows the report of the reminders action to be made by the user as depicted (in Fig. 6c): 'Vehicle Assigned, check the Availability; Chosen Vehicle is Available, 1= Available. 0=Unavailable (Vehicle_Available) Need Updated for Continue Reasoning!'

The domain knowledge was gained from interviews and converted to 73 rules of which 40 rules were jobs creating and reminder for incident handling. Each rule represents a piece of knowledge, and all the rules in the rule base together constitute the domain knowledge, by rules' 'chain' structure. Fig. 7 is an example of part of the reasoning chain that shows the relationship between the rules.

IX. Conclusions

This paper discussed the 'Internet of Things' application to smart waste management system, and outlines the research motivation of this project. The UK has a plasterboard waste disposal issue because of the hazardous reaction of land filled plasterboard waste with organic waste producing H2S gas emissions. The imbalanced geographic distribution of recycling facilities within the UK results in high transportation cost of recycling both in term of time and finances. Based on the understanding of the 'Internet of Things' concept, this paper proposes a 4-layer framework for a smart waste management system based on the 3 layer model of IoT, but extended to match the application domain.

From the framework and 'Internet of Things' concept, a smart waste management system solution is proposed based on a case study from a local SME waste recycling company. The system is a combination of RFID technology and Rule-Based Knowledge Management technology. The system can schedule the waste collection and provide guidance to operation staff either as normal or incident handling instruction, such as road hold ups or vehicle breakdowns etc. in addition, the logistic records of the waste can also be used for tracking waste movement which can provide verification and authentication for both public and government scrutiny.

Reference

[1]. H. Weber Rolf, "Internet of things - Need for a new legal environment?," Computer Law & Security Review, vol. 25, pp. 522-527, 2009.

[2]. DEFRA, "Waste Strategy for England 2007," Department for Environment, Food and Rural Affairs, 2007.

[3]. DEFRA, "Government Review of Waste Policy in England 2011," Department for Environment Food and Rural Affairs, 2011.

[4]. V.Ovidiu and F. Peter, "European Research Cluster on the Internet of Things," in Internet of Things - Globe Technology and Societal Trends, O. Vermesan and p. Friess, Eds.: River Publishers, pp.67-99, 2011.

[5]. F. Anthony, "CASAGRAS DRAFT White Paper WP6:Applications in the emerging Internet of Things," 2009.

[6]. S. Sensing_China, "Premier Jiabao Wen visit Wuxi Technology Centre," 2009.

[7]. MIIT_of_China, " Internet of Things White Paper of China (2011)," China Academy of Telecommunication Resarch of MIIT, 2011.

[8]. Z.Lirong, Zhang Hui, Han Weili, Zhou Xiaolin, He Jing, Zhang Zhi, Gu Yun, and Wang Junyu, "Technologies, Applications, and Governance in the Internet of Things," in Internet of Things-Global Technological and Societal Trends, O. Vermesan and P. Friess, Eds., 2011.

[9]. Z.Lizong, Atkins Anthony S., and Yu Hongnian, "Application of RFID Technology and Knowledge Hub for Logistic Support in Scrapped Type Recycling," in 9th Informatics Workshop for Research Students June, Bradford UK: pp.190-195, ISBN 978 1 85143 251 6, 2008.

[10]. S. Atkins Anthony, Zhang Lizong, and Yu Hongnian, "Application of Knowledge Hub and RFID Technology in Auditing and Tracking of Plasterboard for Environment Recycling and Waste Disposal," in 10th International Conference on Enterprise Information System- ICEIS Vol. IV, pp.190-196 . ISBN:978-989-8111-48-7, 2007.

[11]. Z. Lizong, S. Atkins Anthony and Y.Hongnain "RFID Technology in Intelligent Tracking Systems in Construction Waste Logistics using Optimisation Techniques," in 4th SKIMA (International Conference of Software, Knowledge and Information on Management Applications) Paro, Bhutan 2010.

[12]. Z.Lizong, S. Atkins Anthony, and Y.Hongnian, "RFID Technology in Smart Management System of Internet of Things in Construction Waste Logistics," in 2011 2nd International Conference on Management Science and Engineering (MSE 2011) Chegndu, China: Southern Illinois University Carbondale, In press, 2011.

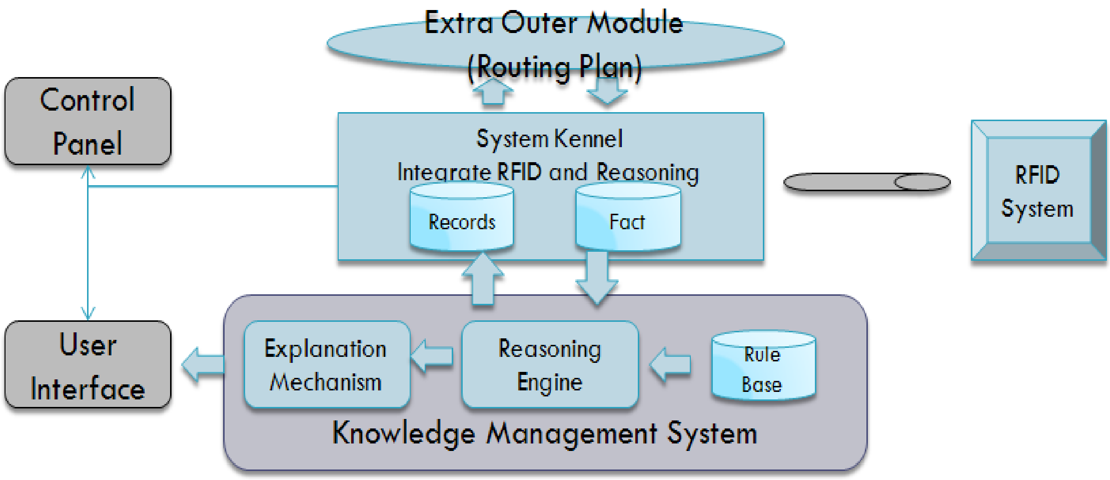


Fig..1, The 4-layer Structure of Waste Management System[11]

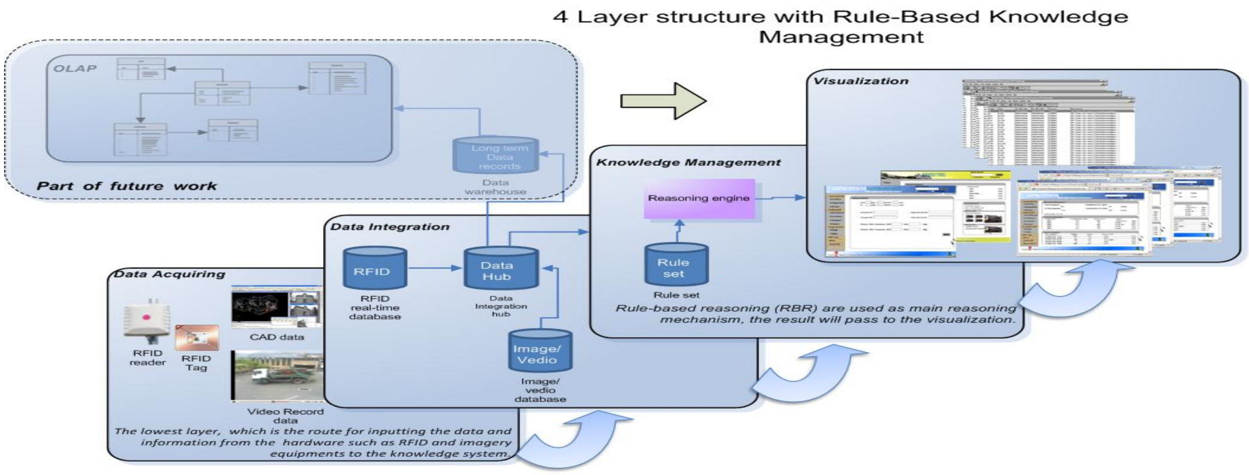


Fig.. 2, Proposed System Structure of the Waste Management System[11]

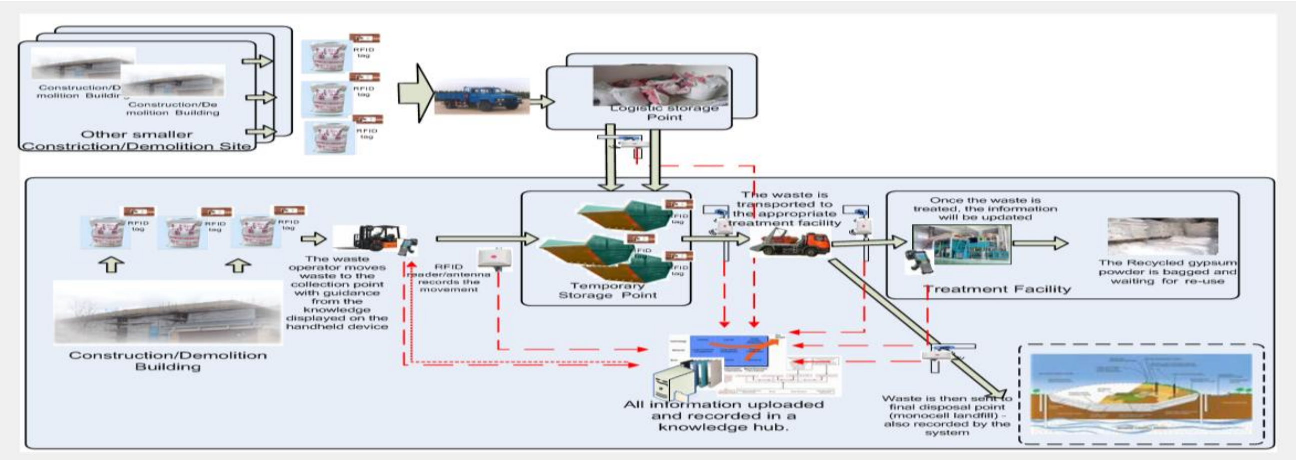


Fig.. 3, Technology View of System Structure

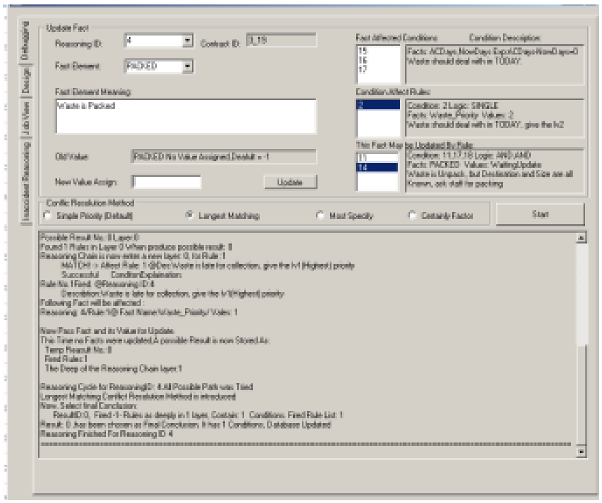
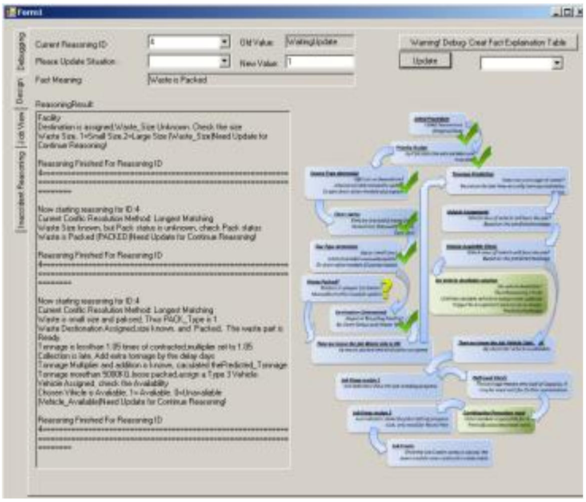
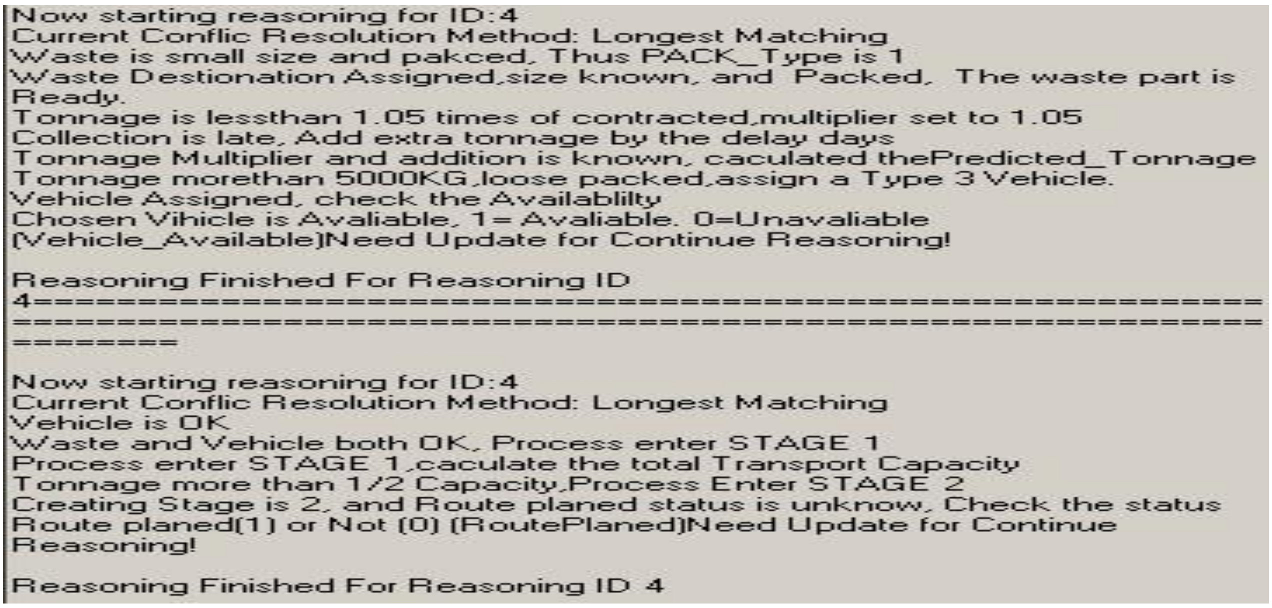


Fig. 6a) Debug Interface



b) The User Interface


Now starting reasoning for ID:4
Current Conflic Resolution Method: Longest Matching
Waste is small size and pakced, Thus PACK_Type is 1
Waste Destionation Assigned,size known, and Packed, The waste part is Ready.
Tonnage is lessthan 1.05 times of contracted,multiplier set to 1.05
Collection is late, Add extra tonnage by the delay days
Tonnage Multiplier and addition is known, caculated thePredicted_Tonnage
Tonnage morethan 5000KG,loose packed,assign a Type 3 Vehicle.
Vehicle Assigned, check the Availablilty
Chosen Vihicle is Avaliable, 1= Avaliable. 0=Unavaliable
[Vehicle_Available]Need Update for Continue Reasoning!

Reasoning Finished For Reasoning ID
4==

Now starting reasoning for ID:4
Current Conflic Resolution Method: Longest Matching
Vehicle is OK
Waste and Vehicle both OK, Process enter STAGE 1
Process enter STAGE 1,caculate the total Transport Capacity
Tonnage more than 1/2 Capacity,Process Enter STAGE 2
Creating Stage is 2, and Route planed status is unknow, Check the status
Route planed(1) or Not (0) [RoutePlaned]Need Update for Continue Reasoning!

Reasoning Finished For Reasoning ID 4

Fig. 6C) Reasoning Procedure Explanation /Report

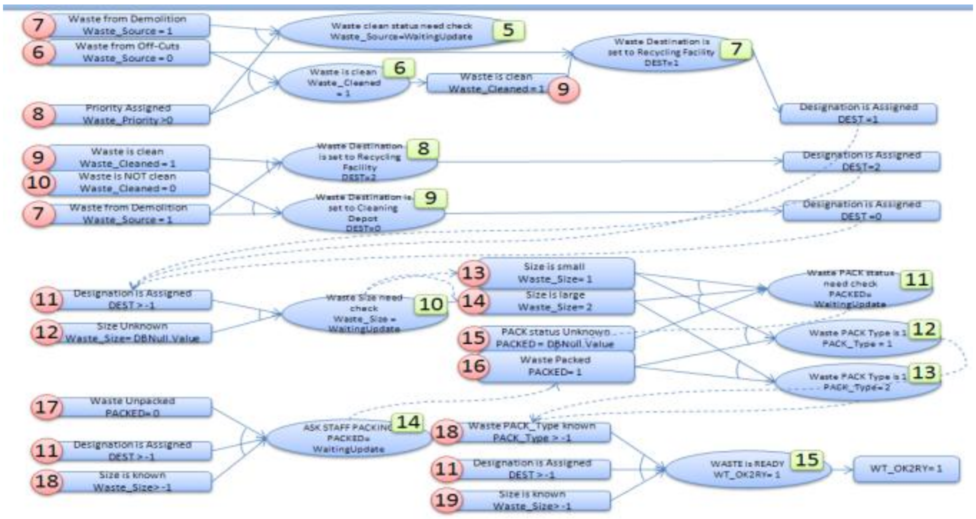


Fig. 7. Part of the Reasoning Chain

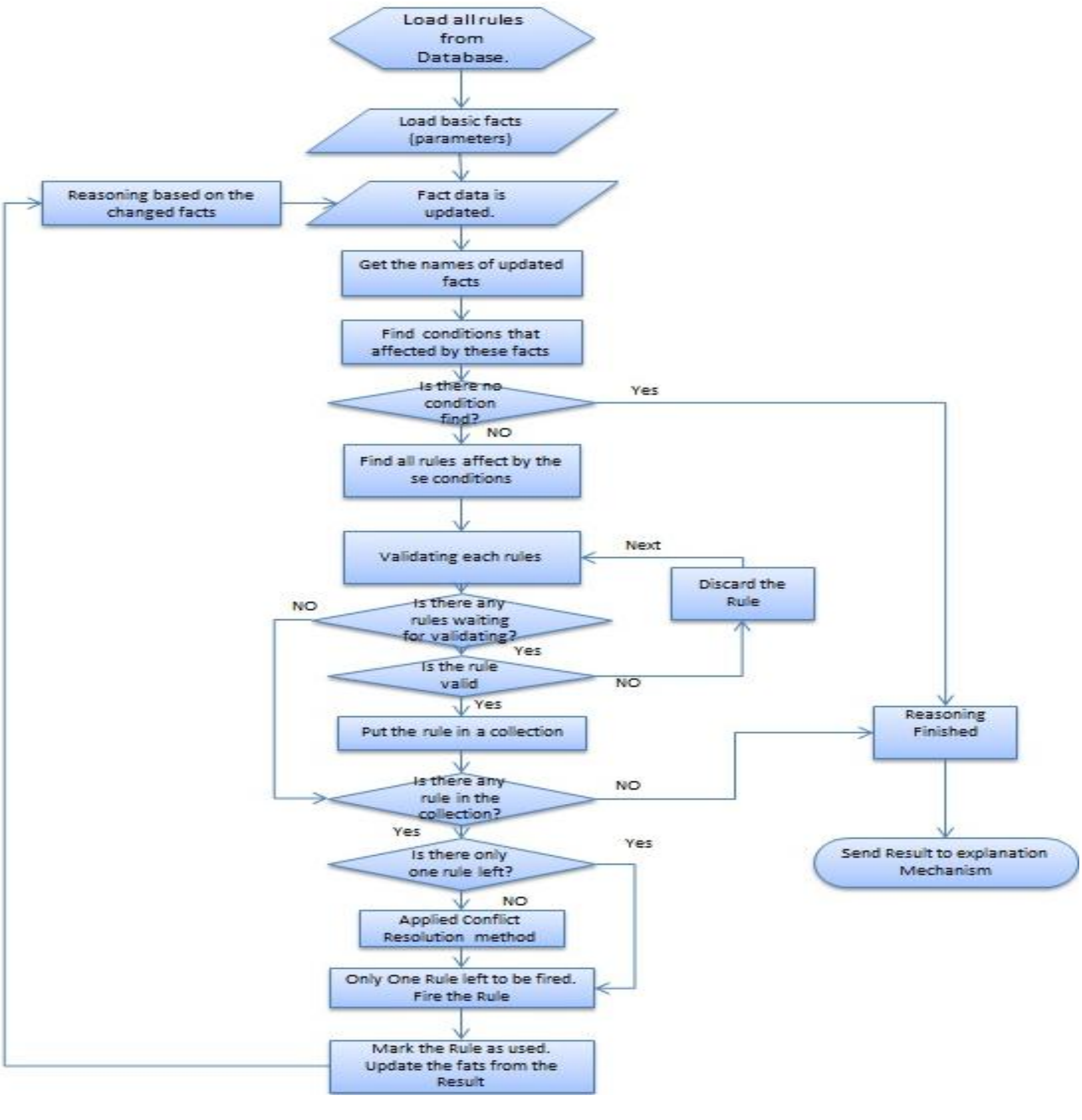


Fig. 5 Flowchart of Reasoning Engine Procedure