Product lifecycle information acquisition and management for consumer products

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Abstract

Purpose – This paper aims to capture and manage the product lifecycle data for consumer products, especially data that occur in distribution, usage, maintenance and end-of-life stages, and to use them to provide information and knowledge.

Design/methodology/approach – A lifecycle information acquisition and management model is proposed, and an information management system framework is formulated. The information management system developed is then used in actual field trials to manage lifecycle data for refrigeration products and game consoles.

Findings – It has been demonstrated that valuable services can be delivered through a lifecycle information management system.

Practical implications – Lifecycle information management systems can open new horizons for product design which are sustainable and environmentally sensitive. They also contribute to the wider exploration of eco-design and development of next generation consumer products (e.g. smart home appliances).

Originality/value – Existing lifecycle information systems cannot support all phases of the product lifecycle. They mainly manage the lifecycle data only during the design and manufacture stages. Lifecycle data during distribution, usage, maintenance and end-of-life stages are usually hard to acquire and in most cases lost. The lifecycle information management system developed can capture them, and manage them in an integrated and systematic manner to provide information and knowledge.

Keywords Product life cycle, Information management, Consumer goods

Paper type Research paper

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1. Introduction

A typical product lifecycle involves various phases which include design, components/materials acquisition, manufacture, distribution/sale, use, service/maintenance and recycle/end-of-life treatment. Data arise at each stage in the lifecycle and need to be acquired and managed in an integrated and systematic manner to provide timely and accurate information to various stakeholders (e.g. manufacturers, recyclers, suppliers). However, lifecycle data occurring in distribution, usage, maintenance and end-of-life stages are usually hard to acquire and in most cases lost. There were some research studies (e.g. "Whitebox" project) which investigated the acquisition of product usage data, but they were mainly concerned with the data acquisition rather than data management. In order to address the need of systematically managing the acquired lifecycle data to close the information loop, we have developed a comprehensive product lifecycle information management system for consumer products in association with a European Commission funded project entitled "Environmental Life-cycle Information Management and Acquisition for consumer products (ELIMA)" (Simon *et al.*, 2004). The distinct feature of this lifecycle information management system is that it can receive and manage lifecycle data from domestic appliances occurring in distribution, maintenance, usage and end-of-life in an integrated and systematic manner to provide information and knowledge for decision-making.

There are commercially available software packages for product lifecycle management (PLM). For example, mySAP Product Lifecycle Management (mySAP PLM) provides a single source of all product-related information needed for collaborating with business partners and supporting processes such as product innovation, design and engineering, quality and maintenance, and control of environmental issues (mySAP PLM, 2006; Gulledge *et al.*, 2004). The ENOVIA software portfolio from Dassault Systems enables businesses to manage various types of data and resources, including CAD drawings and assemblies, Bill of Material (BoM), various documents, etc. (ENOVIA, 2006). However, these software packages mainly manage the product lifecycle data arising at product design and manufacture stages, they cannot manage the lifecycle data occurring during distribution, usage and maintenance, which have huge potential in creating value for stakeholders involved, especially for manufactures and recyclers (Moore *et al.*, 2000; Simon *et al.*, 2000).

A model of lifecycle information acquisition and management for consumer products proposed within the research study includes intelligent data unit (IDU) and information management system. An IDU is an electronic device comprising sensors, controller, memory and communication interface. Each product is equipped with an IDU to acquire the data typically occurring at usage and distribution stages (Moore *et al.*, 2000; Simon *et al.*, 2000). The acquired lifecycle data are then transmitted to the lifecycle information management system. The lifecycle information management system consists of database management system (DBMS), communication manager, information engine, security management, and a series of service components (e.g. report generator, scheduler). The information management system formulated was used in field trials within ELIMA project to manage lifecycle data for refrigeration products and game consoles as examples of white goods and brown goods, respectively. It has been demonstrated that valuable services such as remote monitoring services, remote diagnostic services, and use pattern analysis can be delivered through the information management system.

The paper is structured as follows: Section 2 reviews related work. Section 3 introduces a lifecycle information acquisition and management model for consumer products. Section 4 details the analysis and design of the framework for lifecycle information management systems. In Section 5, the information management system formulated is used to manage the lifecycle data for exemplar white goods and brown goods products. The discussions are presented in Section 6.

2. Related studies

Some research studies in relation to lifecycle information management systems are reviewed, which include enterprise information systems, product lifecycle data and dynamic data acquisition.

2.1 Enterprise information systems

In recent years, enterprise information systems have been deployed to record and process details of all the business transactions of an organisation (Bose, 2006). These software systems capture a rich set of data that contain valuable information to a business enterprise (McAdam and Galloway, 2005). Enterprise information systems usually include enterprise resource planning (ERP), customer relationship management and supply chain management (Shang and Seddon, 2002; Chang, 2006). ERP provides a centralised IT application for business processes and functions within a company or manufacturer (McAdam and Galloway, 2005; Peslak, 2006). ERP focuses on addressing production planning and scheduling, inventory management, cost, and other physical aspects of the production process. Customer relationship management manages the relationships with customers, including the capture, storage and analysis of customer information (Rowley, 2004). It typically focuses on managing sales and order processes. Supply chain management is the process of planning, implementing, and controlling the operations from supplier level to production, distribution and ultimately the end customer (Cooper *et al.*, 1997; Tam *et al.*, 2002). It aims to increase productivity by reducing the total inventory level and cycle time for orders (Helo and Szekely, 2005).

Although these information systems can address issues of enterprise resource optimisation, marketing and supply chain management, respectively, product innovation still brings new challenges to manufacturers related to issues such as environmental concerns, improved product reliability, provision of product add-on services. This has resulted in the emergence of PLM solutions for collaborative engineering, product development, and management of projects, product structures, documents, and quality. PLM, defined by a leading independent organisation that provides strategic consultancy to the application of PLM, is termed the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal (CIMData, 2006).

PLM includes management of all product-related information during the lifecycle (CIMData Report, 2002). However, the existing PLM solutions have little capability to acquire and manage the lifecycle data occurring in distribution, usage, maintenance and end-of-life stages. For example, mySAP PLM provides a single source of all product-related information which includes product innovation, design and engineering, quality and maintenance management, and control of environmental issues (mySAP PLM, 2006; Gulledge *et al.*, 2004). The ENOVIA software portfolio from

Dassault Systems enables businesses to manage various types of data and resources, including CAD drawings and assemblies, BoM, various documents, etc. (ENOVIA, 2006). These PLM software packages mainly manage the product lifecycle data arising at design and manufacture stages, they do not manage the lifecycle data occurring during distribution, usage, maintenance.

According to Kiritsis (2004), product life cycles can be classified in three stages: beginning-of-life, middle-of-life and end-of-life. Beginning-of-life phase includes design, component/material acquisition and manufacture. Middle-of-life phase includes distribution, use and maintenance. End-of-life phase includes refurbishment and reuse/recycle. As mature technologies such as CAD/CAM are widely used at beginning-of-life stage, the data and information flow are fairly complete and readily collectable. Data at this stage rarely change during the whole product life cycle. However, the information flow becomes less and less complete from the middle-of-life to the final end-of-life. In most cases, this interrupted information flow can prevent the feedback from user, service provider and recycler back to designers and manufacturers (Kiritsis, 2004). This means the information loop of different lifecycle phases cannot be closed.

2.2 Product lifecycle data

Product lifecycle data can be classified as static and dynamic data (Scheidt and Zong, 1994). Static data, relating to the specification of the product, give details of materials, components and suppliers, configuration options and operation instructions. They are generated at the beginning of product life and rarely change during the lifetime of the product. Normally, the static data include: BoMs, specific component identification, hazardous materials, material content, take-back information, disassembly attributes (e.g. sequence and tools) and recycling information, etc. Dynamic data occur during the distribution, usage and end-of-life. Usually usage data form the major part of the dynamic data and cover use patterns, environmental conditions and servicing actions.

Dynamic data are valuable asset and can yield information in major areas of interest such as marketing, reliability, servicing, preventive maintenance, and end-of-life (Moore *et al.*, 2000; Simon *et al.*, 1998, 2000, 2004). For example, usage data can be used to provide valuable services (e.g. remote diagnostics, remote monitoring), data captured during distribution can help identify and rectify problems that arise, and appropriate analysis of usage data can lead to knowledge about use patterns. However, due to the features of dynamic data, they are usually not complete and difficult to obtain during the product lifecycle. Most existing commercial PLM software packages (e.g. mySAP PLM) in the main manage only static data.

2.3 Dynamic data acquisition

There have been several research studies involving the issue of dynamic data acquisition.

A UK Engineering and Physics Sciences Research Council funded project "Life-cycle Data Acquisition and Devices for Consumer Products and Machines" (i.e. Whitebox) was carried out to investigate the acquisition of dynamic data for consumer products (Moore *et al.*, 2000; Simon *et al.*, 1998, 2000). In the "Whitebox" project, two prototype IDU devices were developed to obtain dynamic data. An IDU is a device that consists of sensors, a controller, memory and data communication interface. It is either embedded into the product or can be an auxiliary device within the product (suitable for legacy products). Dynamic data are obtained from sensors and represent the measured parameters or values calculated from the data. The "Whitebox" project demonstrated that significant benefits could accrue from the use of IDU technology.

The concept of an IDU for the storage of lifetime data first emerged in 1994 (Scheidt and Zong, 1994). However, it was difficult to integrate such functions into electronic and electrical products due to the relative high cost at that time. Other research on IDU includes using devices on electric motors in power tools with a view to increase the motor reusability (Klausner *et al.*, 1998a, b) and recover resources from appliances (Grudzien and Seliger, 2000). The Technical University of Berlin tested the concept of collecting data from fasteners to assist end-of-life disassembly (Seliger *et al.*, 1999).

A number of state-of-art automatic identification (Auto-ID) technologies (e.g. radio frequency identification (RFID)) can be employed to aid in dealing with information capture and dissemination accurately and efficiently during a product lifecycle (Udoka, 1992). Auto-ID is concerned with the automated retrieval of identity of objects and the information about the item to be stored, retrieved and communicated (McFarlane *et al.*, 2003). It usually refers to a suite of technologies: RFID, electronic product code (EPC) and object naming service (ONS). These technologies have become the core of EPCglobal Network (EPCglobal Inc., 2004) which provides the open loop, standards-based environment required for exchange of EPC information (Shih *et al.*, 2005). The RFID technology is a wireless form of automated identification that provides a quick, flexible and reliable way to electronically detect, track, and control a variety of physical objects (Shih *et al.*, 2005). It enables the automatic product identification thus minimising the errors caused by manual handling and reducing the cost (Parlikad and McFarlane, 2006; Kelly and Erickson, 2005). The EPC is an industry standard for product identification (Brock, 2001). It is a 96-bit code of numbers embedded in an RFID tag on individual product (McFarlane, 2002), and links to an on-line database to provide a secure way of sharing product-specific information. The information is not stored directly within the EPC code; instead the code serves as a reference for networked information. The ONS provides a global lookup service for the query of the URL address of manufacturer's EPC information system for the product carrying the corresponding EPC (McFarlane, 2002; Shih *et al.*, 2005).

Auto-ID technologies have been used in ELIMA project (Bodenhoefer *et al.*, 2004) and PROMISE project (Kiritsis, 2004). For example, in ELIMA a brown goods field trial, the dynamic data obtained from a PlayStation2 (PS2) was stored in EEPROM within its IDU. RFID technology was used to read the data out from EEPROM and save them into a host computer as an XML document.

The "Whitebox" project and Auto-ID technologies were mainly concerned with dynamic lifecycle data/product identity acquisition rather than data management. An integrated view of the whole product lifecycle to close the information loop in different phases of a product lifecycle still remained to be addressed. This involves the issue of product lifecycle information management.

3. A product lifecycle information acquisition and management model

In order to acquire dynamic lifecycle data and manage them in an integrated and systematic manner to close the information loop, each product can be equipped with an IDU to acquire dynamic data (especially usage data), and the data obtained should be transmitted to a lifecycle information management system where information and knowledge can be generated. A model of lifecycle information acquisition and management proposed for domestic appliances is shown in Figure 1.

Lifecycle information acquisition and management for consumer products is a composition of hardware (e.g. IDU), software (e.g. information system), communication facilities (e.g. internet), and suitable management tools (e.g. data management) all integrated to generate information and knowledge. In terms of implementation and deployment, the physical lifecycle information management system can be a high-performance central server or a cluster situated at the manufacturer site. Lifecycle data acquired from a set of similar products via corresponding IDUs are transmitted to the central server over wide area networks (e.g. Broadband) where appropriate processing and analysis can be performed. Since, each product has a unique ID, the lifecycle data are identified by the ID so that they can be distinct from others. In terms of security, only authorised stakeholders such as supply chain stakeholders, recyclers can have privileges to access the information system and the level of access will necessarily be controlled.

Product lifecycle information management is implemented in such a way that it provides a business platform for manufacturers to interact with various stakeholders such as supply chain stakeholders, distributors, customers, maintenance providers and reuse/recyclers. This solution features both B2B (i.e. business to business) and B2C (i.e. business to customer) commercial activities. For example, access to the data and information coming from supply chain stakeholders and recyclers falls under the category of B2B, whilst access to data and information coming from end-users falls under B2C.

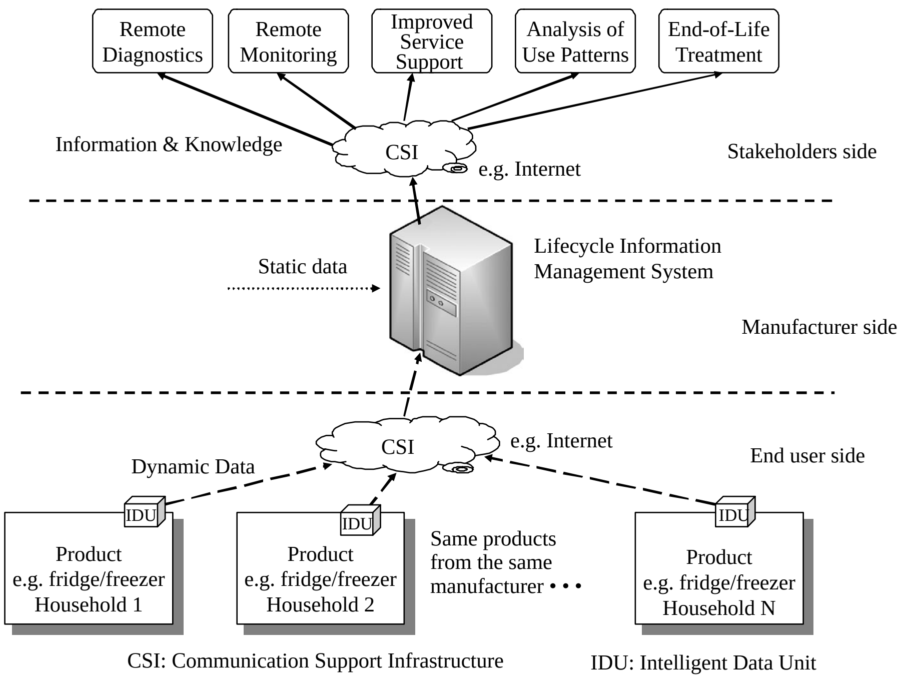


Figure 1. A lifecycle information acquisition and management model for consumer products

4. Formulation of a lifecycle information management system framework

Product lifecycle information management system is a crucial part in the model defined. In this section, the major elements of the framework of lifecycle information management system for consumer products are described, and some of the challenges presented are discussed.

4.1 Three-tier reference architecture

A three-tier reference architecture for a product lifecycle information management system for consumer products has been formulated, as shown in Figure 2. Three tiers are introduced as follows:

(1) External world – comprises of various lifecycle information management actors such as IDU, manufacturer and recycler.

(2) Lifecycle data management – this encompasses the core lifecycle data management business logic. Major components that have been identified in this tier include: communication manager, security manager, information engine, service components, and web-browser based interface. As there are a broad spectrum of data sources and information types encountered in such a system, XML is employed as a neutral format for data presentation, communication and exchange.

(3) DBMS – consists of a data store with a range of management components. The DBMS provides persistent storage and database management functions to house product lifecycle data and information.

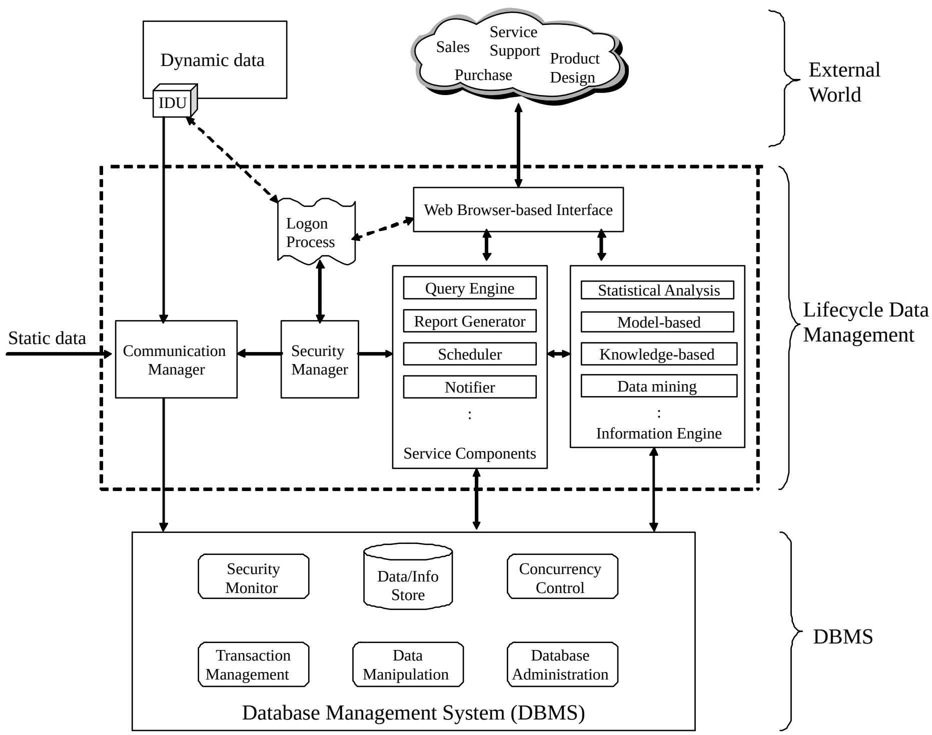


Figure 2.
Product lifecycle information management system reference architecture

4.2 Data handling

Lifecycle data that are collected or stored can be a single value (e.g. an accumulative value up to the point of collection), or a list of series values (e.g. logging a particular physical property where data are logged at fixed time intervals or when an event happens). This determines a need for some structural information in addition to raw data to provide a certain pre-defined format or standard so that a data processing algorithm or logic can be applied and ambiguities can be avoided. The structure of the data is usually given by a schema document, which usually indicates sequence allowed and nesting hierarchies of data elements. A schema document is often used for format verification, data presentation and communication.

A dynamic data structure schema was developed to facilitate the handling of the dynamic data. It was formulated based on the data acquisition modes. An XML schema, which is a formalisation of the constraints expressed as rules or a model of the structure applied to an XML document (Connolly and Begg, 2002; Vlist, 2002), has been employed to present the schema as an XML document. Based on this structure schema, the specific dynamic data structure can then be defined and consumed by components such as communication manager, information engine, security manager, etc.

4.3 Communication manager

The communication manager is a core component responsible for receiving lifecycle data and storing the data. The development of a communication manager is challenging due to the diversity of the dynamic data structures, different types of IDU, various communication protocols (e.g. TCP/IP, GSM) and different back-end DBMS, etc. The way we formulated the communication manager is summarised as follows:

- should support TCP/IP-based file transfer and live data transfer;
- should decouple the DBMS-specific layer (e.g. MySql, Oracle) and the dynamic data-specific layer using a neutral format layer; and
- should provide interfaces to accommodate data transfer in other protocols.

File-based dynamic data transfer is an effective mechanism for transferring the life cycle data, where data are collected and stored as XML or ASCII file format (e.g. CSV) in a local computer. In order to support this transfer mode, a web-based file upload mechanism was provided for dynamic data to be transferred to the remote lifecycle information management system. We adopted an off-the-shelf component called JUpload Applet (JUpload Applet, 2004) to support the upload of multiple files by choosing files separately or collectively, or by just clicking an individual file folder containing data files to be uploaded. The operation sequence for uploading file(s) to the information system is shown in Figure 3. The user chooses files to be uploaded using the file upload Applet provided. The file(s) received are then verified against the corresponding data schema before data are extracted from the file. The extracted data are then stored in the database.

The live data transfer means that dynamic data are constantly transferred into the information system in a form of data stream. As the data are transferred live, the size of the data and the interval between each data transmission are uncertain, namely, they are random and dynamic. In order to tackle these problems, a web service was developed to support this transfer mode. This web service exposes some APIs which can be called in a software program to transfer the live data stream to the information system.

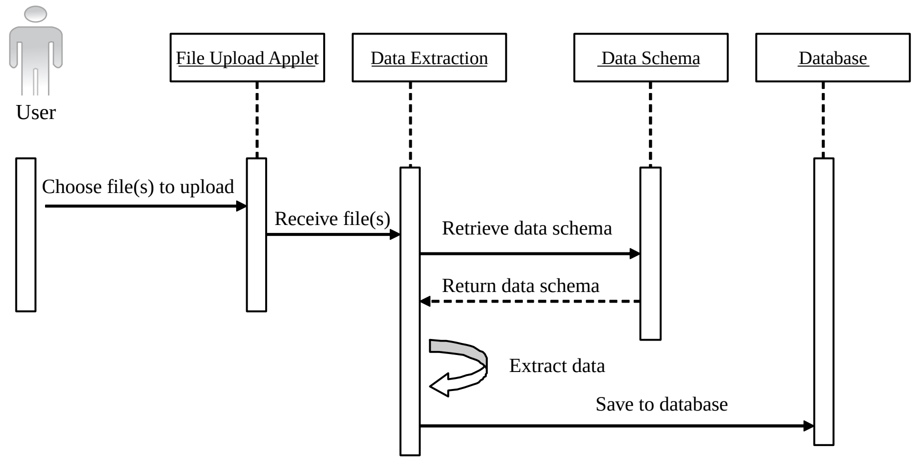


Figure 3.
File upload operation

A corresponding translation engine then needs to be developed by using the defined dynamic data structure to extract the data and save to the database.

4.4 Information engine

The information engine component is designed to provide two mechanisms for quantitative analysis of data:

(1) on-line data analysis; and

(2) transformation and download of data into an Excel spreadsheet format for off-line analysis.

On-line data analysis in this paper refers to data analysis which is carried out on-line using statistical functions and analysis tools provided within the lifecycle information management system. This means that the information engine should provide the capabilities to allow users to selectively choose the dataset for analysis, and should have an in-built library of statistical functions and analysis tools. These present two main challenges:

(1) Once data are displayed as a table in an HTML web page, how can we flexibly choose the dataset based on rows or columns, just as we do in Excel? It is known that the HTML tabular data cannot support random data selection and data sorting.

(2) How can the information engine provide a library of statistical functions and analysis tools.

The design and implementation workflow of on-line data analysis is shown in Figure 4. In order to be able to select the dataset from the HTML table, a Java Applet is developed to display the data in an Excel look-and-feel spreadsheet, where manipulations such as random data selection and data sorting can be carried out. It also supports the whole data column shift to the right or left for easier data comparison and selection. A LiveConnect (Flannagan, 1997) mechanism proposed by Netscape is employed to address the problem of bi-directional communication between the client-side Applet and server-side JavaBeans.

Considering many statistical functions and analysis tools are standard routines (e.g. correlation, histogram) which can be found in some popular analysis and

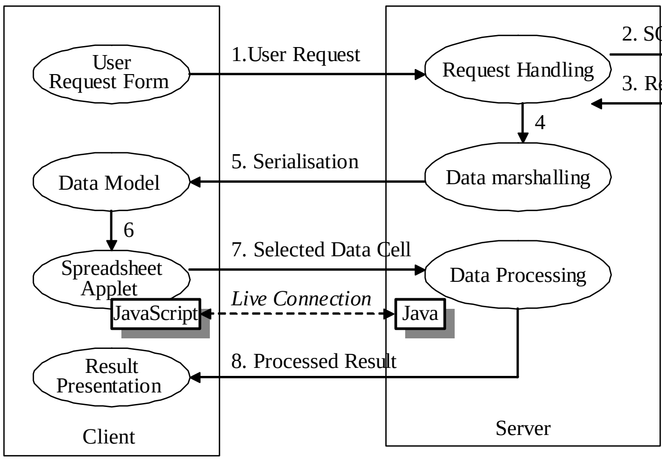


Figure 4.
Workflow for on-line data analysis

simulation software packages (e.g. Excel, SPSS, MatLab), we adopted a solution of developing a connector which can connect the lifecycle information system to analysis routines provided by analysis software packages. As Microsoft Excel contains many predefined or built-in formulas known as worksheet functions (e.g. SUM, AVERAGE), we developed a connector to link to these Excel worksheet functions by employing Microsoft COM technology. A screenshot of an Excel spreadsheet-based Java Applet and analysis tools is shown in Figure 5.

Downloading data and saving them in an Excel spreadsheet format (.XLS) for off-line analysis is common practice used in many companies, as this format is well supported by major analysis software packages such as Excel, SPSS, and MatLab. In order to support this route, we provided functionality which can transform and present lifecycle data in an Excel spreadsheet and save them in. XLS format.

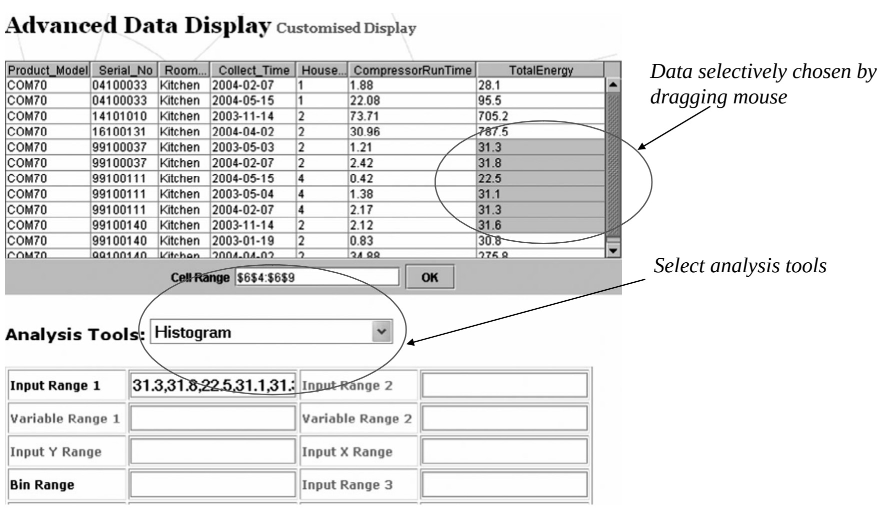


Figure 5.
Screenshot of Excel spreadsheet-based Java Applet and analysis tools

4.5 Security manager

The security manager provides security control in three levels, i.e. log-in access control, data access control and functionality access control. This three-level security access control is achieved by employing the "role and session paradigm" which can be described as follows: the authorised user will be granted a password and a role. The password is used for login access control, while the role is closely associated with a session which determines the level of functionality access and data access. Once a user who plays a certain role logs into the system, a corresponding session is created and determines functionality and data can be accessed. When a user logs into the system, the three-level access control mechanism is invoked, and a new "session" based on the "role" the user plays is created.

The security manager pre-defines a series of roles such as administrator, design and development, recycler, etc. Each role is associated with the security profile, which is a collection of functionality access privilege level and data access privilege level. When establishing a user login account, the password will be required to create and the role will be required to assign. One user can play different roles, which means the same user with different roles has a view of different functionality and data.

5. Test cases

The product lifecycle information management system formulated has been used to manage the lifecycle data within two pan-European field trials featuring the PlayStayion2 (game consoles) and fridge/freezer (appliances) in the ELIMA research programme. ELIMA was a major European Commission-funded framework research project with eight partners that aimed to develop better ways of managing the lifecycles of products and thus reduce their environmental impact. One of the objectives of the ELIMA project was to perform two related field trials, where product lifecycle data is acquired through an IDU and transmitted to a corresponding product lifecycle information management system (Bodenhoefer *et al.*, 2004; ELIMA Seminar, 2005). In the ELIMA field trials, fridge/freezer appliances and game consoles (i.e. PS2) were chosen as exemplar products of white goods and brown goods, respectively. Two types of IDU (i.e. EEPROM- and GSM modem-based) were devised and fitted into different product models of fridges/freezers, while one type of IDU was developed for the PS2 employing RFID technology and some auxiliary sensors and interface components.

The test approach adopted can be summarised as:

(1) Building two specific product lifecycle information management system prototypes.

(2) Using the prototype systems to demonstrate that the system can provide useful information and knowledge.

(3) Evaluating test results. The evaluation involved testing the following criteria:
   - the dynamic data can be acquired;
   - the dynamic data can be transferred to the system and stored in a database; and
   - product lifecycle data can be managed to generate useful information and knowledge.

5.1 Management of lifecycle data for fridge/freezer appliances

A fridge/freezer information management system (FFIMS) was created using the framework developed, and it has been demonstrated that FFIMS can provide a monitoring service and energy consumption advice.

5.1.1 Scenario. Lifecycle data from a freezer (model FZR82, serial number 14100075) was acquired and transmitted to the FFIMS. The customer wishes to know how the product is performing and what events have occurred since the product has been in use.

5.1.2 Background. In the white goods field trial, 95 participants agreed to have a log taken of the lifecycle data of their fridge/freezers. Apart from logging specific fridge/freezer data (e.g. compressor run time, door open times), the FFIMS also logged energy consumption data and temperature values every minute, and logged current and voltage values every 3 hours. All the data gathered were transmitted to the FFIMS. Analysis of these data allows the profile of the fridge/freezer usage to be established. The security manager of FFIMS ensures the customers can access information concerning their fridge/freezers (e.g. energy consumption, surrounding environment) and events that have arisen (e.g. sensor faults, power off) at any time and from any location where they can access the internet.

5.1.3 Remote monitoring. From the lifecycle data acquired and its transmission to FFIMS, the freezer (model FZR82, serial number 14100075) was monitored throughout the field trial. Figure 6 is a screenshot of the freezer remote monitoring information. It shows that from the field trial start date to 14 May 2004 there were 24 power-off events[1]. The freezer temperature setting was always set to "3" during the trial.

5.1.4 Energy consumption advice. One of the benefits of the remote monitoring service was that it can provide a customer with advice of how to reduce fridge/freezer energy consumption. For example, correlation of the compressor run time with the number of door open events for COM95 and FZR82 models show that the more times the fridge/freezer door opens, the more energy is consumed. A sample plot for model COM95 is shown in Figure 7. Therefore, advice can be given that reducing the

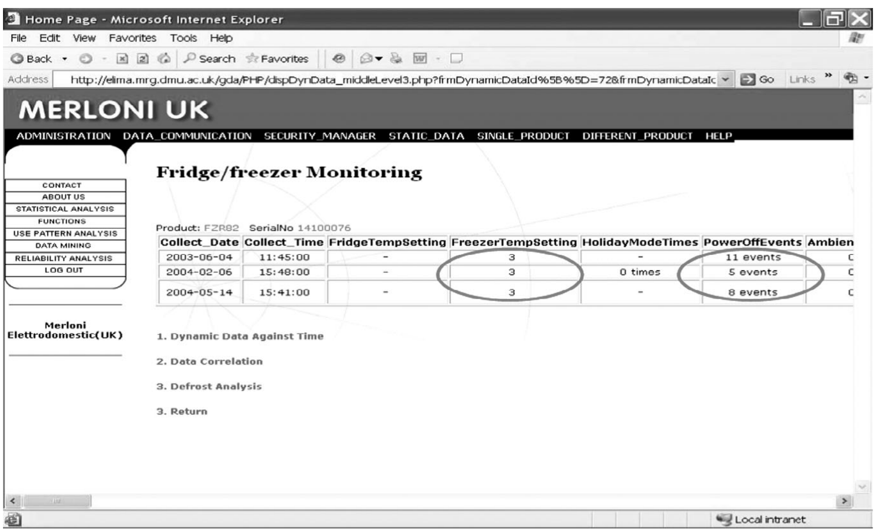


Figure 6.
A screenshot of freezer remote monitoring information

door open times can be effective in reducing the energy consumption (ELIMA Seminar, 2005).

5.2 Management of lifecycle data for PlayStation2

A PS2 information management system (PSIMS) was created using the framework and one aspect of which is the ability to deliver a remote diagnostics service and use pattern analysis.

5.2.1 Scenario 1. Remote diagnostics

> A user reports that his PS2 experienced a disturbance (PS2 serial No: 0719952J136). However, it is unknown whether this shock has damaged the CD-drive. Assume the acquired lifecycle data have been transmitted to the PSIMS over the internet.

5.2.2 Background. For the PS2 game console, medium or strong shocks can cause damage of the CD drive (misalignment of the laser). A defective CD-drive might start operation but stop after initial turns. In this case, the maximum speed detected for the defective CD-drive is <500 rpm.

5.2.3 Remote diagnostics. In PSIMS, the dynamic data collected for unit 0719952J136 are shown in Figure 8. In the left-hand table of dramatic events, it shows a shock occurred (event type 8) at 8 February 2004 13:10:00. Shock level 2 means this PS2 unit encountered a disturbance moving from the vertical to a horizontal position. In the right-hand table of standard events, it can be noted that all recorded events related to CD-drive are low speed after 8 February 2004 13:10:00. This means that after the shock damage to the CD-drive occurred, as each recorded speed is below typical operational speeds (of $\sim$ 2,000 rpm). Analysis of results from the recorded data can indicate to maintenance technicians that the CD drive might be faulty.

5.2.4 Scenario 2. Use pattern analysis

> The PS2 console can be operated in two different positions: horizontal or vertical. We would like to know which mode in which country is preferred by customers. Knowing this can help inform "Marketing" as to regional preferences, and can help "Design & Development" enhance the product design.

5.2.5 Background. Use pattern analysis is carried out based on the actual dynamic data rather than using questionnaire data where data might not be complete and accurate. Thus, the accuracy of the use pattern analysis can be assured.

5.2.6 Use pattern analysis. The basis for the analysis involved 178 units used in four countries, namely, Germany, UK, Spain and Italy. Lifecycle datasets for 178 PS2 units

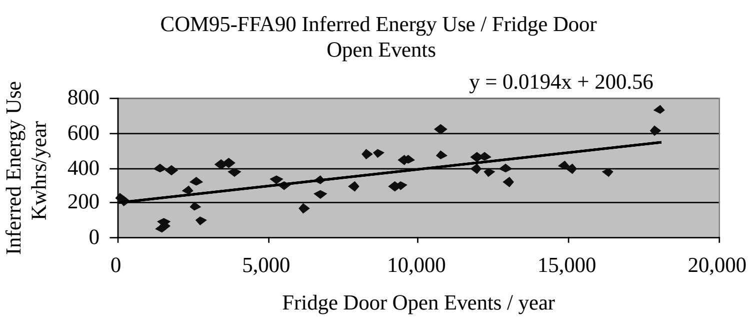
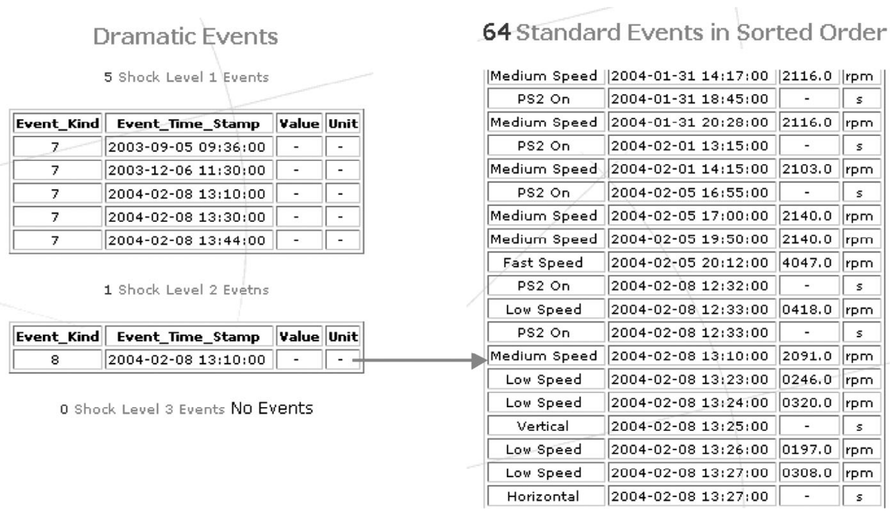


Figure 7.
Compressor cycles v. fridge door openings per year



Dramatic Events

5 Shock Level 1 Events

Event_Kind	Event_Time_Stamp	Value	Unit
7	2003-09-05 09:36:00	-	-
7	2003-12-06 11:30:00	-	-
7	2004-02-08 13:10:00	-	-
7	2004-02-08 13:30:00	-	-
7	2004-02-08 13:44:00	-	-

1 Shock Level 2 Evetns

Event_Kind	Event_Time_Stamp	Value	Unit
8	2004-02-08 13:10:00	-	-

0 Shock Level 3 Events No Events

64 Standard Events in Sorted Order

Medium Speed	2004-01-31 14:17:00	2116.0	rpm
PS2 On	2004-01-31 18:45:00	-	s
Medium Speed	2004-01-31 20:28:00	2116.0	rpm
PS2 On	2004-02-01 13:15:00	-	s
Medium Speed	2004-02-01 14:15:00	2103.0	rpm
PS2 On	2004-02-05 16:55:00	-	s
Medium Speed	2004-02-05 17:00:00	2140.0	rpm
Medium Speed	2004-02-05 19:50:00	2140.0	rpm
Fast Speed	2004-02-05 20:12:00	4047.0	rpm
PS2 On	2004-02-08 12:32:00	-	s
Low Speed	2004-02-08 12:33:00	0418.0	rpm
PS2 On	2004-02-08 12:33:00	-	s
Medium Speed	2004-02-08 13:10:00	2091.0	rpm
Low Speed	2004-02-08 13:23:00	0246.0	rpm
Low Speed	2004-02-08 13:24:00	0320.0	rpm
Vertical	2004-02-08 13:25:00	-	s
Low Speed	2004-02-08 13:26:00	0197.0	rpm
Low Speed	2004-02-08 13:27:00	0308.0	rpm
Horizontal	2004-02-08 13:27:00	-	s

Figure 8.
Remote diagnostics: a screenshot from PS2 lifecycle information management system

are housed in the PSIMS. This analysis was conducted using an Excel spreadsheet generated by PSIMS. The results (Figure 9) show that, among 178 units, there were 105 units which were played in a horizontal attitude (>90 per cent horizontal operation) and 21 units which were played in vertical attitude (>90 per cent vertical operation). The result showed that about 60 per cent of the users preferred the horizontal orientation, about 12 per cent of the users preferred the vertical orientation and 28 per cent of the users utilized the PS2 in both positions (Bodenhoefer *et al.*, 2004).

The analysis indicated that most customers, irrespective of country, prefer putting the console in a horizontal orientation (60 per cent) when playing games. This result could influence future design and development of the product. The analysis also showed that changing the attitude is unusual for the majority of the users. This implies that most users just select an initial operation orientation depending on their local environment. Once the position is selected, it will not usually be changed.

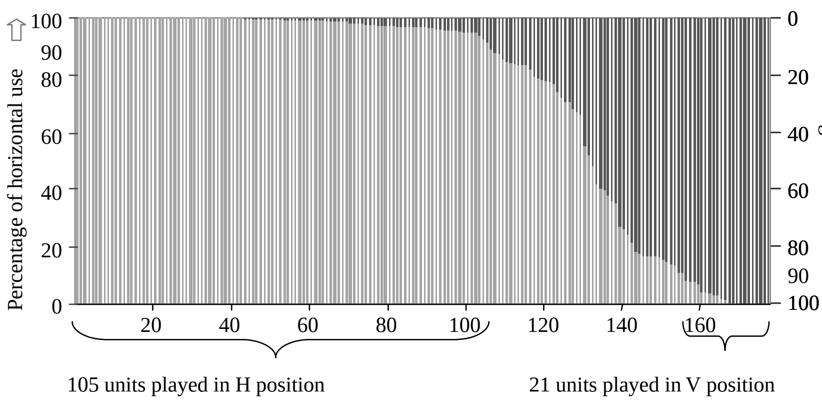


Figure 9.
Operation modes of PS2 consoles

6. Discussions

In addition to facilitating valuable services as illustrated in two field trials, lifecycle information management system can also provide useful information and knowledge to help domestic appliance manufacturers address environmental concerns required within EU directives and legislation (e.g. WEEE, RoHS)[2]. For example, WEEE (Directive on Waste Electrical and Electronic Equipment), RoHS (Directive on the Restriction of Hazardous Substance) (EUROPA, 2006) require manufacturers to take the responsibility for the collection, disposal and recovery of the product at end-of-life as well as to restrict the use of hazardous substances. This means manufacturers/suppliers/recyclers need to share a range of information in respect of the components they use in their products. This information include items from different suppliers, items from non-EU suppliers, material content of parts, traceability of parts (e.g. due to upgrade), cost of take-back and collection, etc. The lifecycle information management system formulated can be of significant assistance for these purposes. It can assist practicing managers/designers to open new horizons in product design which are sustainable and environmentally sensitive, and contribute to the wider exploration of eco-design and development of next generation consumer products (e.g. smart home appliances).

The development of lifecycle information management systems requires a good understanding of engineering disciplines such as mechanical, electrical and manufacturing engineering in addition to information and communication technologies. From the research study, we learnt that the challenging issues for manufacturers to develop and deploy such a system include:

- developing appropriate IDU technology to ensure good quality data can be acquired;
- live transmission of the acquired data to the information system;
- developing powerful statistical and analysis capabilities for data mining to provide domain-specific information and knowledge; and
- developing user-friendly interfaces whilst ensuring the security of commercially sensitive product life data.

The lifecycle information acquisition and management system formulated does not currently adopt Auto-ID technologies. For example, the product identities do not incorporate the EPC code, and information system is not an EPC-enabled information system which can be looked up through ONS. However, refinement of lifecycle information management system to incorporate the EPCglobal Network is not a difficult issue to address.

The product lifecycle information acquisition and management model proposed was devised for consumer products. However, there are other sectors in industry which can benefit from such a model. For example, in the automotive industry, life cycle data generated during the use of the vehicle can be collected, stored, transmitted, managed and analysed through the application of the model proposed. The authors are confident that lifecycle information acquisition and management model proposed in this paper can be extended to apply to most product sectors. Theoretically, technologies such as sensors, Auto-ID, wireless communication can be applied to any physical products (e.g. cup, table) to acquire their life cycle data and transmit them to the information system.

7. Conclusions

A product lifecycle information acquisition and management model for consumer products is proposed, and a lifecycle information management system conforming to this model has been developed. The information system formulated was used to manage the lifecycle data of game consoles and fridge/freezer appliances during the ELIMA field trials. It has been demonstrated that both lifecycle information management systems can effectively manage the product lifecycle information in an integrated and systematic manner to provide valuable services. The lifecycle information management system can open new horizons for product design in terms of realising sustainable and environmentally sensitive solutions, and contributes to the wider exploration of eco-design and development of next generation consumer products (e.g. smart home appliances).

Notes

1. Power was often switched off for some fridge/freezers during the trial.
2. In EU, a series of directives have been proposed towards the sustainable development as regulation and legislation (e.g. WEEE, RoHS).

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