Supporting the Reuse of Parts Based on Operation Histories of Products and Preference of Consumers

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Abstract

For the effective re-use of parts, each re-usable part is required to be under appropriate management throughout their life cycle. A hindrance to the circulation of re-used parts is behavior of users. The flow of re-used parts around the user is uncontrollable and unpredictable. Authors are proposing “Part agent system” that is the combination of network agent called “Part agent” and radio frequency identification chip RFID. This paper discusses the mechanisms how Part agents use the operation history of the parts and the user's preference on maintenance of the parts to support their effective reuse.

1 Introduction

To achieve the effective re-use of parts, authors are proposing a system that is the combination of network agent and RFID where the network agent is assigned to a particular part and is programmed to follow their real counter-part wherever it goes. We call this agent a "Part agent" [1][6].

Behavior of users is a hindrance to the circulation of re-used parts. The flow of re-used parts around the user is uncontrollable and unpredictable in spite of the great effort of the manufacturer. The cause of such instability may include user’s inability to manage all the parts in his products as well as his inaccessibility to the correct information on maintenance.

The purpose of our proposal of Part agent is to give users appropriate advices on the re-use of parts and to promote the circulation of the re-used parts. In previous work [2], it has been shown by simulation of Part agents that advices can be generated in consideration to user's preference and operation histories of products. However, it is revealed that the retrieval of operation history of a part is difficult when it is a reused part. It is also understood that some means are required to provide users with the information of part. In this paper, we discuss the mechanism how Part agents retrieve the operation history of the part and how they provide information to the owner of part.

First, the concept of Part agent is described in section 2. In section 3, how the operation history and user's preference is used in maintenance is discussed. Proposed mechanisms are discussed in sections 4 and 5 how Part agents retrieve the operation history and how the information is provided to users. Preliminary results of the prototype system for these mechanisms are shown in section 6. Section 7 summarizes the paper.

2 Life Cycle Support of Products Using Network Agent

We are proposing Part agent system that manages the life cycle of mechanical parts by using network agent and RFID. The system is to manage all the information on the individual part throughout its life cycle on the assumption that network environment is available ubiquitously.

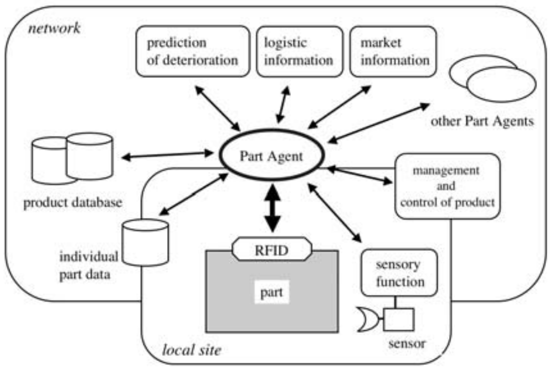

Fig. 1.1. Conceptual Scheme of Part Agent

2.1 Concept of Part Agent

The concept of Part agent is shown in **Fig. 1.1**. In our scheme, Part agent has the following functions.

(a) It follows the corresponding part through the network. Part agent uses Radio Frequency Identification (RFID) [5] attached to the part as the key to find and to identify its corresponding part.

(b) It gets the design information of part from the product database in the network, provided by the manufacturer.

(c) It manages the current information of the corresponding individual part, including assembly configuration, historical records, deterioration level, environmental status, etc. that may be stored in databases in the network, in the local site or in RFID.

(d) It may activate the sensors in the local site and gets the information of part such as applied load and wear, and environmental information around the part such as temperature.

(e) It uses the application in the network to decide the action of the part. We assume applications are available that provide Part agents the information such as prediction of deterioration, logistic information and market information. Part agent uses the information as well as the current status for its decision.

(f) Based on the decision, it requests the operator or function that controls the product to take the necessary action.

Combining these functions, Part agent autonomously and intelligently supports the life cycle of the part. Based on this concept, we are currently developing functions using network agents and RFIDs to realize Part agent system.

2.2 Part Agents to Support User's Activity [2]

As described previously, user's behavior is a hindrance to the circulation-oriented society. Part agent is applied to provide users with advices on maintenance of parts, which will promote the circulation of re-used parts.

We have performed simulation where Part agents give users advice on replacement of the part. Advice is created with the following factors in consideration.

- Current and predicted deterioration
- Availability of the alternative part in market
- Cost required for the replacement
- Logistic cost to transfer the part to and from the maintenance site,
- Predicted operation cost
- Environmental load

In this simulation, the models for deterioration, logistic cost and operation cost are linear to the duration of operation. The model of environmental load is constant except for production and disposal. Though the models are simple, the re-use of parts achieves less environmental load when the factor of environmental load is large.

We have added the function to this system that allows user's preference on maintenance to the simulation. Following kinds of users are assumed that are;

- Users who cares only about the current deterioration of the part,
- Users who cares about the current deterioration of the part and the deterioration of the replacement part in market,
- Users who cares about the trade-in price of the part and the price of replacement part in market,
- Users who cares about all the characteristics, i.e., the current deterioration of the part, its trade-in price, the deterioration and price of the replacement,

Result of the simulation shows that the users who only cares about the current deterioration of the part, in other words, who will not accept Part agents advice pay more than other type of users.

The simulation showed that, if several types of users with different preference in maintenance exist, Part agent will promote effective circulation of re-used parts by providing appropriate advice to users.

3 Maintenance Using Operation Histories of Products and Preference of Consumers

Maintenance of products is provided depending on the characteristics of product, maintenance cost and owner's strategy on maintenance. In some cases, mechanical parts are repaired only after their breakdown. In other cases, diagnosis is performed periodically and parts are replaced when symptoms such as large deterioration are detected on the diagnosis. More advanced maintenance may predict the process of deterioration based on the operation history of the part, such as monitored motor revolutions against time.

We have implemented a prototype system for Part agent. In the system, three types of maintenance are provided as shown in **Fig. 1.2**. Type (a) is the corrective maintenance where parts are repaired only after their breakage. Type (b) and (c) are the preventive maintenance. For (b), the degradation of part is measured by sensors or calculated based on the operation data. Failure is predicted if the cumulative value reaches the threshold and the part is replaced. For type (c), in addition to these values, the operation history is used to determine if the part should be replaced or not.

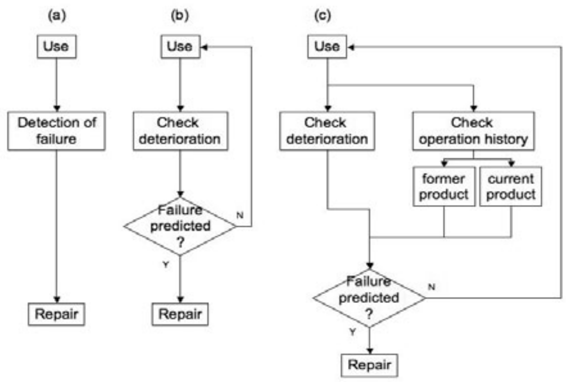

Fig. 1.2. Options of Maintenance; (a) Corrective Maintenance, (b) Preventive Maintenance Based on Accumulated Data on Deterioration and (c) Preventive Maintenance Based on Operation History.

When the part is a reused one, its operation history must be collected not only from the current product data but also from the former product that the part once belonged. Details of proposed mechanism for collecting the operation history is described in the next section.

Parts or products that are re-used through used parts market such as cars or small computers have difficulty in reducing total environmental burden of their whole life cycle. For manufacturers, it is difficult to predict the behavior of their customers that affects the quality and quantity of take-back parts. Such information is a requisite to perform efficient and effective circulation oriented production.

For users of products, it is not easy to behave truly in favor of the environment, as it is difficult to give adequate maintenance to every goods they are using. Users may not know the precise deterioration level of their products or the available options of the maintenance. It is also difficult to decide what is good for environment, as they do not have a measure to evaluate the greenness of a specific option. Furthermore, users may want an option on their own strategy. Some users may prefer new version of products, and others may prefer to use it longer.

We consider that the behavior of users is essential element to reduce the environmental burden of total life cycle of products and that it is important to provide adequate assistance to the users. Mechanism to provide the owner of the part with its information is discussed in section 5

4 Using Operation Histories of Products

Use of the operation history is an important element to realize an advanced maintenance system. However it also brings out an issue when we consider the re-use of parts.

Usually, operation history is recorded for the product and not for each part to avoid redundancy. When a failed part is taken back and repaired to be re-used in a different product, its operation history in the former product will be lost.

4.1 Requirement of Operation History

If the maintenance can be achieved with simple values such as accumulated duration of usage, operation history is not required. Operation history is required when the diagnosis criteria are changing and a single value to be monitored cannot be determined beforehand.

When a phenomenon that leads to the failure of part is found, new diagnosis criterion will be established and the operation history of each part should be analyzed according to the new criterion. We consider that recalls of vehicles may be fallen into this type. The current recall is performed for all the possible vehicles due to the lack of traceability of operation history. If the function to check the operation history on site, unnecessary recalling will be avoided.

Operation history is also required for complex cases where multiple diagnosis criteria are combined.

4.2 Retrieval of Operation History

For Part agent to retrieve operation history, the following procedure shown in **Fig. 1.3** is developed for the prototype system.

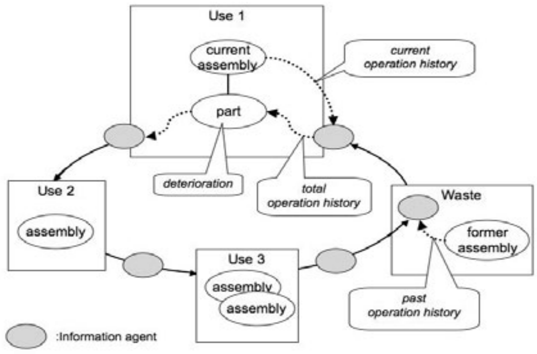

Fig. 1.3. Retrieving the Operation History.

When diagnosis requires the operation history of a part, the part agent creates an information agent to find the former and current assembly that contains the part. The information agent visits every candidate sites and checks if the designated assembly exists in the site. If it finds the assembly, the required operation history is obtained. The information agent goes back to the site of the original Part agent with the retrieved information on the operation history.

For assemblies disassembled, the part agents representing the assembly should be kept for some period in order to provide operation history in response to the request from its former parts that are re-used. Special site shown as Waste in the figure is established for that purpose.

4.3 Technical and Social Issues

Retrieving the operation history contains both technical and social issues.

In the above procedure every sites are checked to find the former assembly. However, it may not be feasible to check all possible sites. We need a robust mechanism to trace the former assembly, especially when we cannot rely on the manufacturer of the part for that role.

When an assembly is taken back for maintenance, it may be reused with new alternative part installed for the failed part, but it may be discarded. The information of operation history of those discarded assembly should be kept somehow. Our solution in the prototype system is to establish the Waste site shown above, but an issue still remains who manages such a site in real world.

When a part is reused, the owner of the current assembly that contains the part may be different from the owner of the former assembly that contained the part in the past. It is difficult to determine who is the owner of the operation history of a part that is recorded in the former assembly.

There exist privacy issue [4] for the retrieval of operation history. Users may not accept the idea that the operation history of his or her product is transferred to the other person. Careful management is also required for keeping information of discarded assemblies.

Security is another big issue for not only managing the operation history but also for Part agent system itself. Mechanism that assures the valid motion of agents should be developed. Effective encrypting of the information of agents or RFIDs is also required to avoid the stealing.

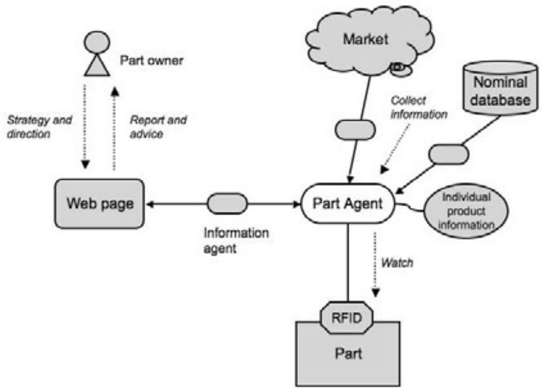

Fig. 1.4. Communication of Part Owner with Part Agent.

5 Consumer's Preferences

As described above, one of the problems for consumers is that they cannot perform the maintenance on his parts according to his preference.

Preliminary results of previous research [2] suggest that when consumers have various preferences in maintenance, the adequate support of their preference promotes the effective reuse of parts.

Method is required for users to communicate easily with Part agent. For that purpose, we are developing web-based communication between users and part agent as shown in **Fig. 1.4**. Part agent sends subordinate information agent to the web site. Report and advice from Part agent is provided via web page to the user. Inversely, user can send the preference of maintenance strategy or the direction to the Part agent through this mechanism.

6 Usage of Operation History in Prototype System

Prototype system for Part agent is developed with function using the operation history in maintenance.

6.1 Prototype Part Agent System

Prototype Part agent system is developed based on agent function of CORBA system Voyager [3]. The developed system has ability to communicate RFIDs but it is not used in the following simulation where only Part agents moves in the system. The supposed product is a vacuum cleaner, an assembly with five components that are a motor, a body, a hose, a nozzle and a filter.

Fig. 1.5 shows the display of the system. Windows in the figure shows, from top left in clockwise,

- Production site that produces Part agents,
- Assembly site that assembles 5 components in one assembly,
- Two Use sites where the products are operated,
- Maintenance site that disassembles assembly and send re-usable parts back into assembly site, and
- Waste site that keeps disassembled assembly information.

6.2 Results on Use of Operation History

Simulation is performed based on the following assumptions. Part is assumed to deteriorate by the turns of motor that turns 600 revolutions per minute. Duration of operation is defined randomly from 5 to 20 minutes. For each operation of cleaner, each part is deteriorated. The level of deterioration is represented with a single integer value. The level of deterioration for each part increases 2 to 6 in one operation. The rate of deterioration depends on the kind of part. When the level of deterioration reaches 200 the part breaks down. For each operation whose duration is more than 15 minutes, motor is assumed to receive additional damage. Furthermore, part breaks down accidentally with the probability of once per 30 operations.

Two kinds of maintenance are assumed; corrective maintenance that is performed after the detection of breakage and preventive maintenance that is performed based on the prediction. Cost of maintenance is assumed respectively 1000 for the former and 100 for the latter.

Prediction is made based on the deterioration level of the part derived from the cumulative turns of motor. Different threshold value is assigned for each kind of part to send the part to maintenance.

For motors, additional prediction may be performed

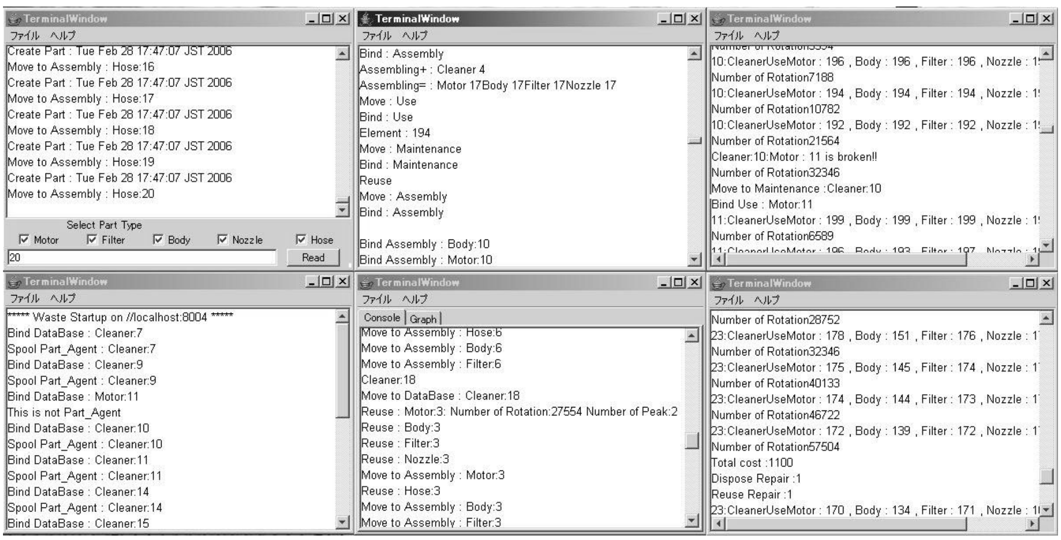

Fig. 1.5. Display of Part Agent System.

based on the number of damages caused by the operation with long period. This damage information is stored only in assembly and, although it is a single value, is supposed to be operation history in this simulation. If the maintenance requires this information, Part agent should send a subordinate information agent to find the assembly that contains the part now and one that contained the part previously.

Three types of maintenance are performed for comparison. Type A is the case where corrective maintenance is applied to all the parts. Type B is the case where predictive maintenance is applied for all the parts whenever possible. If the cumulative turns of motor exceeds 100,000 under this type of maintenance, the agent suggests repair of the assembly. Type C is the case where the operation history is checked for motors in addition to the predictive maintenance based on cumulative turns of motor. If the cumulative turns of motor exceeds 100,000 under this type of maintenance, the agent sends information agent and suggests repair of the assembly based on the historical damage information acquired by the information agent.

30 sets of vacuum cleaner are manufactured in the simulation. Part agent system as well as the mechanism searching the former assembly to obtain the operation history works well. Maintenance using the operation history is successfuly performed.

The result of simulation is shown in **Figs. 1.6** and **1.7**. **Fig. 1.6** shows the cumulative cost of maintenance against the number of operations of cleaner. The difference between corrective maintenance and preventive maintenance is due to the difference of their cost. Effect of use of the operation history can be seen.

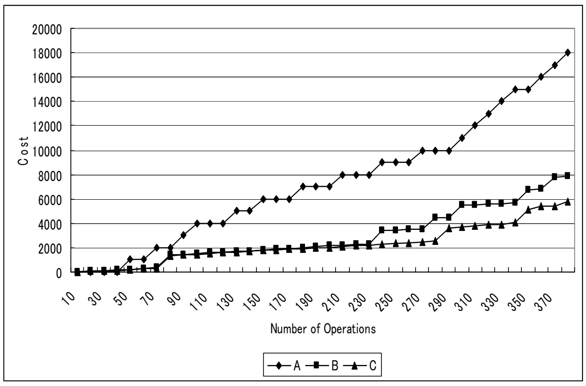

Fig. 1.6. Comparison of Maintenance Cost.

Fig. 1.7 shows the number of maintenance actions. Even if the preventive maintenance is performed, corrective maintenance is also required due to the randomness of failure and unpredictable cause of deterioration. Examining the operation history reduces the number of corrective maintenance.

Though the result shows the effectiveness of the scheme, it is not fully persuasive becouse the simulation is based on a simple model. We should further research the applicability and effectiveness of the method.

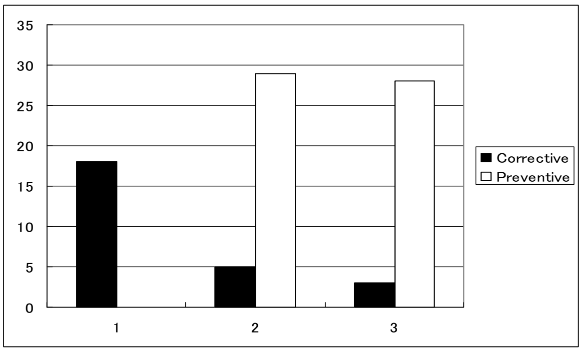

Fig. 1.7. Comparison of maintenance actions.

7 Conclusion

To achieve the effective re-use of parts, Part agent system is proposed that helps the users on maintenance of the part. In this paper, two functions of the system are focused. The mechanism is proposed to obtain the operation history stored in the former assembly that contained the part previously and web-based communication mechanism between user and Part agent is proposed. Preliminary result of simulation on retrieval of the operation history is reported. Related remaining issues are also discussed.

Acknowledgement

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