An Analysis of Patterns for Automating Information System Operations

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Abstract: - Automation of operations is essential for effective and efficient information system operation. For the very first step towards establishing a design methodology for system management operations, operation patterns based upon analysis of existing operations conducted in data centers have been proposed. For each pattern, feasibility of automation and recommendation for improvement is analyzed. The correlation between operation patterns and the objectives of operations has been also analyzed.

Key-Words: - system management, workflow, patterns, automation, autonomous computing

1 Introduction

The more our society relies upon information systems, the more effective and efficient information system management is demanded. Although emerging technologies like “cloud computing” [1] and “SaaS” [2] make system management task invisible from ordinary IT users, the importance of the information system management grows larger because the task is centralized to the service providers and ineffective and inefficient system management cause huge damage for both of service provider and their users.

Automation of operations is effective for making system operation activities more reliable and reducing their cost. As reported in [3], even for small-scale environments like a laboratory in a department, an automation of management tasks reduces great amount of time and troubles. For large-scale data centers managing more than 10,000 servers, the cost reduction effect of automation of system management operations is enormous.

Although various automation tools for system management have been proposed [4] [5][6] [7][8] and some products have appeared on the market, the level of automation in actual data centers is not sufficient. A lack of established design methodologies suitable for automated system management and operation is one of the reasons for this situation.

Ever since proposed by Gamma et al [9], “Design pattern” is adopted in wide variety of information technology area [10][11] as a useful and powerful tool for good design. As the first step towards establishing a design pattern catalogue for system management operations, the authors propose a model for system management operations and patterns for operations based on analysis of operations in an actual information system and analyze patterns in terms of automation and objectives of operations.

2 Model of system management operations

2.1 Management activities of information systems

According to ITIL (Information Technology Infrastructure Library)[12], which is a collection of good practices of information system management activities, a lifecycle of application is defined in as

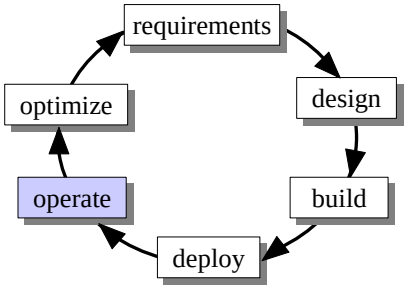

Fig. 1: Application lifecycle defined in ITIL

shown in Fig.1. In this paper, system management operations in "operate" phase are discussed.

The purpose of "operate" phase activities is to make the system maintain provision of the aimed functionalities at a satisfactory service level. Without proper system management operations, application systems built with huge amount of development and deployment cost cannot yield expected value.

There are three major objectives of system management operations as follows:

(1) Regular operation: operations performed regularly in normal situation
(2) Maintenance operation: operations performed upon maintenance such as system configuration changes and upgrade or version update of hardware or software.
(3) Emergency operation: operations performed upon a failure or when a symptom of a failure is detected.

Typical operations of these three objectives are listed in Table 1.

System management operations are designed in the design of system management and finally provided as a collection of executable operations. Operations may be provided in a form of operation manuals and executed by human operators, or in a form of script language executed by automation tools.

In order to make operations possible to be executed either manually or automatically, conditions to invoke operations, actions to be taken and prerequites of the actions should be clearly defined for each operation.

Table 1: Typical system management operations

	objective	Typical operations
1	Regular	Invocation, termination, partial termination, restart of the entire sysytem or components of the system Backup of data preparing for system failure Collecting system metrics for evaluation
2	Maintenance	Cofiguration change Software update
3	Emergency	Monitoring sysytem and response to malfunctions

2.2 Model of operations

Operations described above can be defined as workflows regardless of whether they are executed manually or automatically by tools. In this paper, operations are modeled as follows:

(1) An operation is described as a directed acyclic graph (DAG) as shown in Fig.2. The direction of an arc between nodes indicates the order of execution between work units denoted by nodes.
(2) A work unit is categorized in one of four categories as follows:
   Event Detection (E): Detection of a change in status which invokes an operation
   Condition Check (C) : Checking condition of the object related to the operation
   Judgment (J): Selection of a subsequent unit of work based upon results of a condition check
   Action (A): Actions to be taken on the object of the operation
(3) The following restriction is applied to the configuration of the graph:
   (a) The root of the graph must be a single Event Detection node.
   (b) The leaves of the graph must be Action nodes.
   (c) For every Judgment node there must exist at

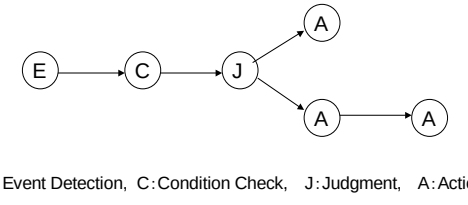

Fig. 2: A sample operation

least one incoming arc from a Condition Check node.

(d) Targets of arcs starting from a Judgment node must be an Action node or Condition Check node.

Although iterations of actions may occur in actual situation, such situations can be expressed by combining DAG's by an event. In this paper, combination of DAG's is not discussed.

Considering natures of system management operations, four restrictions given in (3) are straightforward.

2.3 Detailed categorization of work unit

Management operations can be considered as a workflow. The Workflow Patterns Initiative collects patterns of workflows [13]. This pattern collection focuses on the control flow patterns. To automate operations, whether the work units consist of workflow can be automated is essential. For extracting patterns of management operations, in addition to the patterns of control flow, categories of work units should be analyzed to find patterns.

With observation of existing system management operations, detailed categorization for Event Detection and Action as shown below are obtained;

(1) Event Detection:

Timer monitoring: The operation is invoked when a predetermined time is reached.

Active manual operation: The operation is invoked by an active manual operation by an operator.

Event monitoring: The operation is invoked when a predefined event occurs.

As for Event monitoring, activities like monitoring the status change of monitored objects, monitoring messages or logs output by an operating system, middleware or applications, monitoring the excess of thresholds of predefined metrics and passive manual operations performed by an operator who noticed these incidents are among its examples.

(2) Action:

Notification: Reporting abnormal situation of the system to operators by means of sending an e-mail, buzzer, lamp etc.

Data manipulation: Performing backup, storage or deletion of predefined data for recovering to a previous status, investigation of causes, or preventing further damage to the system.

Recovering action: Performing action to recover the system to the normal status.

3 Extracting operation patterns from existing operations

3.1 Description of surveyed systems

In order to extract operation patterns, system management operations conducted in existing system were surveyed. Table 2 shows a list of systems surveyed to extract operation patterns.

Case 1 is a case of a shopping site on the internet. A system configuration of case 1 is shown in Fig. 3. This system is a typical case of Web 3-tier architecture. Because the site should be available anytime, keeping the system reliable and efficient in terms both of response and throughput, is very important goal of system management. Furthermore, because the system is connected to the Internet and accessed by public, and the system handles customers' private information like credit card numbers and shipping address, for keeping the system

Table 2: A list of analyzed systems

	overview	configuration	Number of operations
case1	shopping site	Web Server:14 AP Server:4, DB Server 4	29
case2	photo upload site	Web Server:3 DB Server:2	17
case3	J2EE base Web system	Web 3 –tire system consists of Web/AP/DB server is assumed	21
case4	J2EE base electronic form workflow system		47

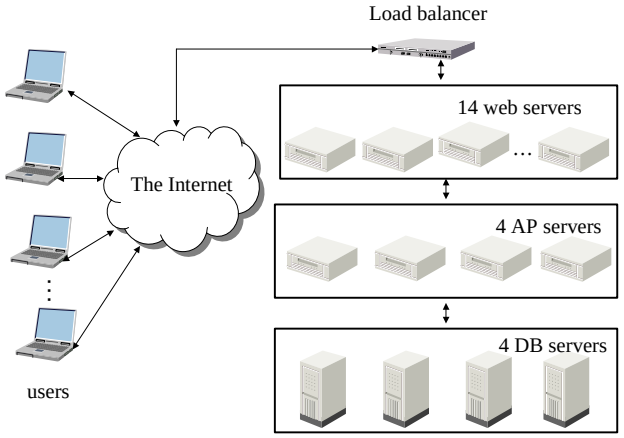

Fig. 3: System configuration of case 1.

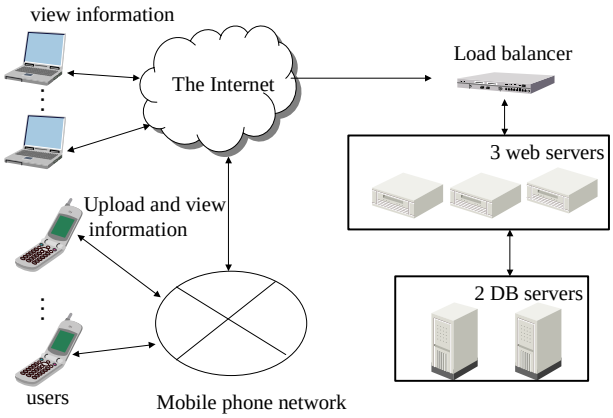

Fig. 4: System configuration of case 2.

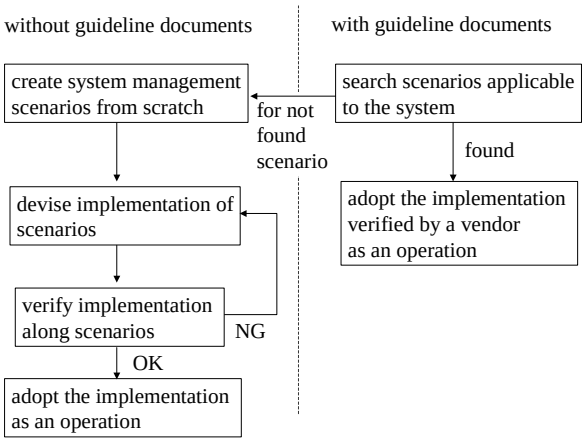

Fig. 5: Comparison of processes for composing system management manual with and without guideline documents

secure operations for system maintenance like software update are important.

Case 2 is a photo upload site. The system configuration is shown in Fig.4. This system is also connected to the Internet and accessed by both mobile phones and PC's. Users upload photos and GPS information of the location the photo shot from mobile phone with camera and GPS features. Users view the uploaded data either by mobile phones or PC's. Requirements for the system management are similar to case 1. A scale of the system of this case is smaller than case 1, because the service of case 2 is still in infancy while the system of case 1 is established business.

As mentioned above, the systems of case 1 and 2 provide services to the public via the Internet. Because in these case system failures may cause a huge impact on the business of the service providers, not only the basic operations such as invocation and termination of systems and backup of data, but also operations for version updating of an application, updating for security, response to spikes of numbers of access, and recovery from system failure are described in the operation manuals of these two systems.

Case 3 is a typical web 3-tier application. In this case guideline documents for system management, which are provided by the vendor of J2EE application server, were surveyed. For each individual system, system management manuals are compiled by customizing the guideline documents. The guideline documents provide collections of best practices along typical system management use cases. Even though using system management functionalities provided by products are described in manuals, when and how to use which functionality is hard to understand without explanation with use case scenarios. By using these guideline documents, the amount of work to design and compose system management manuals is dramatically reduced. With the guideline documents, it is not necessary to create system management scenarios from scratch, devise implementation of the scenarios and verify the implementation, but it is just enough to pick up scenarios fit to the system. Of course, if the scenarios provided by the guideline documents are not sufficient, it is necessary to devise from the scratch. The comparison of processes for composing system management manuals with and without guideline documents is summarized in Fig. 5 as flowcharts. In an extreme case, it is reported that a work takes 2 weeks without guideline documents was accomplished just in a day. Considering these facts, the authors concluded that these guideline documents are more adequate to be surveyed for patterns of system management operations than actual system management manuals composed from them. The very existence of such guideline documents is an evidence of difficulty of system management of complex systems. Because the guideline documents do not assume a particular environment, the system can be used in either intranet or the internet environment.

Case 4 is an electronic document workflow system built upon a J2EE application server. As in case 3, in this case the system management guideline documents provided by the vendor of the system were surveyed. In this case, the system is assumed to be used within an intranet by users inside of an organization. In this case, the guideline documents include both system management operation of

underling J2EE server components and the electronic document workflow applications running top of them. The reason for choosing the guideline documents as a target of surveillance is as same as Case 3.

3.2 Description of patterns

In the classic design pattern catalogue by Gamma, et al. [9], for describing design patterns, following thirteen attributes are used.:

Pattern Name and Classification
Intent
Also Known As
Motivation
Applicability
Structure
Participants
Collaborations
Consequences
Implementation
Sample Code
Known Uses
Related Patterns

In this paper, for describing system management operation patterns following 6 attributes are used.

Category/Sub Category
Corresponding to *Pattern Name and Classification* in [9].
Overview
Corresponding to *Motivation*, *Applicability* and *Consequences* in [9].
Graph representation
Corresponding to *structure* in [9].
In a graph representation, descriptions of the detailed category given in section 2.3 are attached to nodes for work units.
Example
Corresponding to *Know Uses* in [9].
Note on automation
No exactly corresponding attributes in [9], but *implementation* is close.
Remarks
Corresponding to *Related Patterns* in [9].

No corresponding attributes to describe system management operation patterns for *Also Known As*, *Participants*, *Collaborations*, *Implementation*, *Sample Code*.

As for *Also Know As*, there are no other well-known names for the patterns because there is no previous attempt to categorize the system management operations.

As for *Participants*, for the system management operations nodes appeared in the operation are limited as defined in 2.2 of this paper,

As for *Collaboration*, behaviors of collection of operations are beyond the scope of this paper.

As for *Implementatio*n and *Sample Code*, creating source codes is not a purpose of patterns for system management operations.

Table 3: Operation patterns

Category	Sub-category	Pattern ID
Periodic customary	-	Pattern 1
Non-periodic customary	Without Condition Check	Pattern 2-1
	With Condition Check	Pattern 2-2
Notification	Without Condition Check	Pattern 3-1
	With Condition Check	Pattern 3-2
Error Recovery	-	Pattern 4

3.3 Extracted patterns

By analyzing the four cases described in 3.1, four patterns and six sub-patterns were extracted. Table 3 shows the extracted patterns.

Descriptions of each pattern are given below in a format described in 3.2.

Pattern-1: Periodic Customary Operation

Overview: This pattern is used for performing an action like invocation, termination, restart and data manipulation in a periodic manner. A graph representation of this pattern is shown in Fig. 6.

Example: A typical example of an operation of this pattern is daily automatic backup of database invoked by timer

Note on automation: Operations of this pattern are often already automated. Even if an operation is currently operated manually, it is easy to automate the operations in this pattern if the action to be taken can be implemented with software and without

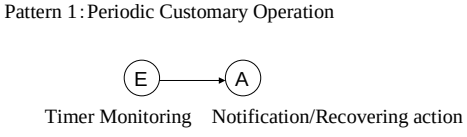

Fig. 6: Pattern-1 Periodic Customary Operation.

intervention by a human operator.

Pattern-2: Non-periodic Customary Operation

Overview: This pattern is used for operations that are customary but not periodic because they can be performed at any time when a certain condition is satisfied or should be performed after completion of another operation for which the termination timing is uncertain. The operations of the Without Condition Check pattern (pattern 2-1) are invoked when monitored events are detected or an operator performs active manual operations. For operations of the With Condition Check pattern (pattern 2-2), prerequisites for performing an Action are checked before performing an Action by the Condition Check work unit and if the prerequisite is not satisfied, the fact is reported to an operator by performing the Action of Notification.

The major difference between Pattern-1 and Pattern-2 is the way the operation starts.

A graph representation of this pattern is shown in Fig. 7.

Example: Software update performed by an operator is an example of Pattern 2-1 with an Active Manual Operation. If the update operation is performed regularly then the operation is Pattern 1 and, if the operation is invoked upon detect of some event such as termination of other operation, then the operation is an example of Pattern 2-1 with an Event Monitoring. Reorganization of database initiated by an operator after checking that the front end system is terminated and ready for database reorganization is an example of Pattern 2-2 with an Active Manual Operation.

Note on automation: If a category of the Event Detection work unit is an active manual operation, due to the necessity of human intervention, it cannot be automated. If the category of Event Detection is event monitoring and events can be monitored by software, the Event Detection work unit can be automated. The possibility of the whole operation being automated depends on whether the Condition Check and Action work unit can be implemented with software only and without human intervention.

Remarks: The major difference between Pattern-1 and Pattern-2 is the way the operation starts.

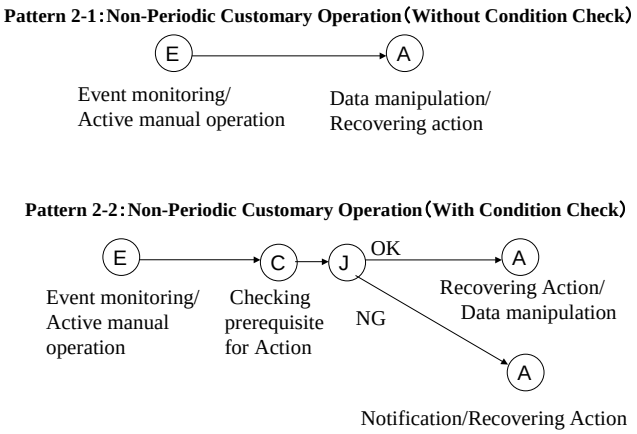

Fig. 7. Pattern-2 Non-periodic Customary Operation

Pattern-3: Notification

Overview: This pattern is used for operations that report the change in the status of a monitored object to an operator to make the operator perform the appropriate action if necessary.

The Without Condition Check (Pattern 3-1) pattern is applied when an object is monitored all the time by an Event Detection work unit and a change of status in a monitored object is reported to an operator by means such as sending an e-mail, sounding a buzzer, or lighting up a lamp. The Operations With Condition Check pattern (Pattern 3-2) is invoked by Event Monitoring or Active manual operation and the Condition Check unit work is performed to check the condition of the monitored object. If a problem is detected, the Notification Action is performed; otherwise no action is taken.

A graph representation of this pattern is shown in Fig. 8.

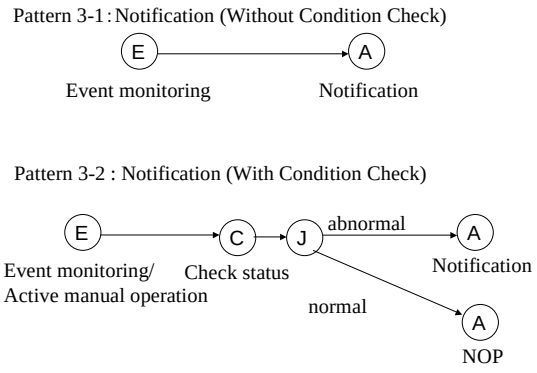

Fig. 8: Pattern-3 Notification

Example: A typical example of operation of Pattern 3-1 is monitoring network by tools [10] and sending e-mail to operators when some network problem is detected. When the monitoring operation is not always active and initiated by an operator, such an operation is an example of Pattern 3-2. If some problem is detected then it is notified to the operator. Such an operation may be initiated by an event like termination of other operation.

Note on automation: Operations of Pattern 3-1 are often automated. Automation of operations of Pattern 3-2 depends upon Event Detection and Condition Check.

Remarks: As mentioned above, the difference between Pattern 3-1 and Pattern 3-2 is the monitored object is always under surveillance (Pattern 3-1) or checked only when some condition is satisfied (Pattern 3-2).

Pattern-4: Error recovery

Overview: This pattern is used for operations for recovering from system failures. An operation of this pattern is invoked upon a status change of a monitored object and after checking prerequisites of actions of Action work units.

A graph representation of this pattern is shown in Fig.9.

Example: An error recovery operation of J2EE server is a typical example of this pattern. There are prerequisite for recovery operations. When an error occurs in J2EE server, processes used in recovery operations may also have problems. Therefore before initiating error recovery actions, such prerequisites should be checked.

Note on automation: Automation of an operation of this pattern depends upon whether work units contained in the operation can be implemented as software without human intervention.

Pattern 4: Error recovery

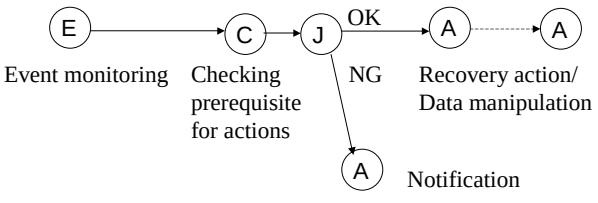

Fig. 9: Pattern-4 Error Recovery

3.4 Summary of relationship between automation and patterns

Relationship between automation and patterns is described in description of each pattern. Summary of them is given in Table 4.

In order to automate operations, the type of Event Detection is important. When the type of Event Detection of an operation is Active manual operation, whether it can be replaced by Event monitoring should be considered. Reasons of human operator intervention is necessary should be reviewed. For example, if the reason is confirmation of the termination of precedent operations by operators, it may be able to be replaced by issuing an event notifying termination of operations or monitoring termination messages by some software tool.

For work units of Condition and Action, possibility of automation depends upon functionality of managed system. Unless the managed system provides function necessary for management operations, it is difficult to automate the operations.

A functionality of work units of Judgment is often supported by system management tools and executed automatically according to rules provided in advance. .

Table 4: Summary of relationship of automation and patterns

ID	pattern	description
1	Periodic customary operation	often automated
2-1	Non-periodic customary operation (without condition check)	depending upon type of Event Detection. If it is event monitoring it can be automated. If it is active manual operation, it cannot be automated.
2-2	Non-periodic customary operation (withcondition check)	
3-1	Notification (without condition check)	often automated but actual actions to be taken are left to operators
3-2	Notification (with condition check)	depending upon type of Event Detection and Condition Check
4	Error recovery	depending upon software implementability of work units contained in the operation

4 Correlation between operation patterns and operation objectives

4.1 Correlation between operation patterns and operation objectives

There are three objectives of system management operation shown in Table 1. Correlation between operation patterns and operation objectives are analyzed for the cases shown in Table 2. The result of the analysis is shown in Table 5.

The Periodic Customary Operation pattern (Pattern 1) is used for regular operation as easily expected.

The Non-periodic Customary Operation pattern (Pattern 2) is used for either regular operation or maintenance operation. The result reflects the fact that maintenance operations are performed not periodically but at the time of an event like software version upgrading.

The Notification pattern (Pattern 3) is used for an emergency operation. Difference between the Notification (without condition check) pattern (Pattern 3-1) and the Notification (with condition check) pattern (Pattern 3-2) is whether managed objects are monitored all the time (Pattern 3-1) or checked upon operators active manual operation or some events.

The Error Recovery pattern (Pattern 4) is used for emergency operations. Operations of the Error Recovery are used for recovering from condition detected as inappropriate. Therefore those are used for emergency operation.

Relationship between the operation patterns and operation objective is summarized in Table 6.

For regular operations, the Periodic Customary Operation pattern (Pattern 1) is mainly used in case 1. In other cases, the Non-periodic Customary Operation pattern is used with exceptional use of the Notification (without condition check) pattern in case 4. This difference is considered to be caused by the difference of automation levels among cases. Because operations of the Periodic Customary Operation pattern are often automated, a level of automation of case 1 is higher than other cases.

For maintenance operations, the Non-periodic Customary Operation (with condition check) (Pattern 2-2) is used in case 1. In other cases, the Non-periodic Customary Operation (without condition check)(Pattern 2-1) is widely used. The reason of this difference is considered that in case 1, conditions to be checked before performing actions are well analyzed and explicitly expressed in system management operations and in other cases such condition checks are implicitly done in active manual operations of Event Detection work units. Therefore, maintenance operations of Pattern 2-1 should be reviewed if there is an implicit condition check.

For emergency operations, there is a difference in usage of the Notification pattern among cases. In case 1, all the notification operation is Pattern 3-1, i.e. most likely automated. In other cases, particularly in case 4, all the notification operation is Pattern 3-2 and operators' active manual operations are necessary.

Table 5: Correlation between operation patterns and operation objectives.

	regular					maintenance					emergency				
	Case 1	Case 2	Case 3	Case 4	total	Case 1	Case 2	Case 3	Case 4	total	Case 1	Case 2	Case 3	Case 4	total
Pattern 1	5	0	0	1	6	0	0	0	0	0	0	0	0	0	0
Pattern 2-1	0	2	2	9	13	0	8	7	24	39	0	0	0	0	0
Pattern 2-2	0	0	7	0	7	10	0	1	1	12	0	0	0	0	0
Pattern 3-1	0	0	0	0	0	0	0	0	0	0	6	3	1	0	10
Pattern 3-2	0	0	0	1	1	0	0	0	0	0	0	1	1	7	9
Pattern 4	0	0	0	0	0	0	0	0	0	0	8	3	2	4	17

Table 6: Summary of relationship between patterns and operation objectives

ID	pattern	objective
1	Periodic customary operation	regular
2-1	Non-periodic customary operation (without condition check)	regular/ maintenance
2-2	Non-periodic customary operation (with condition check)	
3-1	Notification (without condition check)	emergency
3-2	Notification (with condition check)	
4	Error recovery	emergency

4.2 Relationship between operation objectives and automation

Combining Table 4 and 6, relationship between operation objectives and automation is obtained as shown in Table 7.

Table 7: Relationship between operation objectives and automation

ID	objective	Description of automation
1	regular	often automated
2-1	regular/ maintenance	depending upon type of Event Detection. If it is event monitoring it can be automated. If it is active manual operation
2-2		
3-1	emergency	often automated but actual actions to be taken are left to operators
3-2		depending upon type of Event Detection and Condition Check
4	emergency	depending upon software implementability of work units contained in the operation

Automation of regular operations depends upon type of Event Detection. If the type of Event Detection is timer monitoring, the operation is one of Pattern 1 and the operation is often automated. Otherwise, the operation is one of Pattern 2 and again automation depends upon the type of Event Detection.

Automation of maintenance operation depends upon type of Event Detection and Condition Check.

Automation of emergency operation depends upon whether work units consist of the operation can be implemented as software. When the Action is Notification, the operation is often automated. However, for the operations of Pattern 3-1, actual recovery actions should be done by other operations, which are usually not automated but performed manually by human operators. Automation of these activities is important for automation of entire system management activities.

4.3 Study of irregular cases

Among cases analyzed, there are some irregular cases which do not match relationship summarized in Table 6. As shown in Table 5, there is an operation of Pattern 3-2 used for regular operation. Examples of irregular cases are shown in Fig. 10.

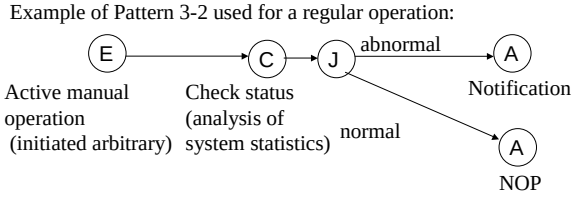

Fig. 10: Examples of irregular cases

The example of a usage in a regular operation is analysis of system statistics stored in a database. This activity of analysis is initiated arbitrarily by operators. As a result of the analysis, when symptoms of performance degradation, shortage of disk space and etc. are found, alarms are notified. In this case, an urgent response to the alarm is not necessary. Therefore, this case is considered as a regular operation.

5. Conclusion

In this paper, the authors propose operation patterns extracted by analyzing existing system management operations. Also, the correlation between operation patterns and operation objectives is described.

Study of patterns of work units is to be done as a next step of research towards an effective design methodology for automated system management,.

The operation patterns proposed in this paper can be used as a guideline for reviewing existing system management operations towards automated management.

Another possibility of the application of operation patterns described in this paper is a pattern based on wizard functionality of a design tool for system management operations. The wizard functionality is beneficial for improving the efficiency and correctness of design of system management operations.

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