Method of Automatically Generating 3DCG-Based Maintenance Training Contents from 2D-Based Storyboards

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Keywords: maintenance training contents, 3DCG, authoring, storyboard

ABSTRACT

We propose method of automatically generating 3DCG-based maintenance training content from 2D-based storyboard. It utilizes attribute tables for each 3DCG object. These tables and definitions automatically generate content from the storyboard. A trial with seven examinees showed that the reduction cost was over 40% compared with an existing content-generation method.

1 Introduction

Skilled laborers such as maintenance workers are declining due to the aging population in Japan. Such laborers are so essential for maintaining social economy that their work activities should be more efficient. Therefore, several maintenance training systems with virtual reality (VR) are being researched and implemented [1] to make it easier for workers to understand operational procedure even without real machines. However, because these systems are very costly to implement, several cost-effective authoring tools have been researched [2]. However, our trial results of using tools based on such technologies revealed that it is still costly for non-experts to oversee making content in their businesses.

In this paper, we propose storyboard-based training content generation technology and evaluate how it reduces costs through testing.

2 Method

2.1 Maintenance work and existing training method

Maintenance work involves both periodic maintenances to prevent faults and fixing failures. Maintenance engineers working at numerous maintenance bases must learn the structures, disassembly procedures, and troubleshooting skills for various machines. (e.g., washing machines, dryers, etc.).

Printed manuals and instructional videos are used for maintenance training for these machines. These manuals are insufficient because they do not include troubleshooting instructions in detail with pictures. Video tutorials can also fail to help maintenance engineers understand positional relationships. For example, when a video zooms in on a part or the instructor's hands, engineers sometimes become confused as to whether the parts are set on the left or right side.

To solve these issues, we propose a three-dimensional computer graphics (3DCG)-based maintenance training system [3]. Fig. 1 shows an example of training content and some instructions. Fig. 1 (2) shows the target device in 3DCG view. Maintenance engineers can operate the 3DCG with a mouse, a touch panel, gestures, or other methods on a PC, smartphone, and tablet. Maintenance engineers can learn the content anywhere.

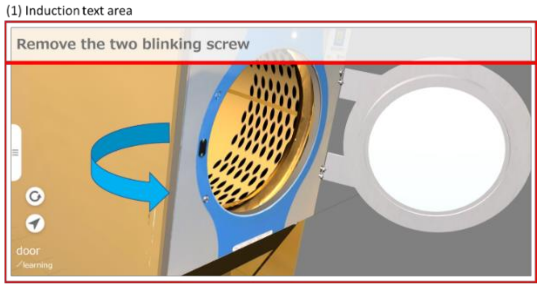

Fig. 1 Display of maintenance training content.

2.2 Generation process for maintenance training content

Fig. 2 shows the process for generating maintenance training content. Content developers select target devices and read existing manuals to understand assembly/disassembly procedures (see Fig. 2 (1) and (2)). They make storyboards from manuals and have them reviewed by authorized people to do so (see Fig. 2 (3)). The storyboards are equal to content specifications. They collect materials for training content such as 3DCG models, pictures, and movies (see Fig. 2 (4)). 3DCG models are made with 3DCG modeling tools. This data is also converted from computer-aided design (CAD) data. The machine parts of the target devices are divided into the cover, computer units, electronic board, and so on. Tools such as a driver, a wrench, and screws can be used for various devices. These tools are registered to authoring tools (see Fig. 2 (5)). The authoring tools enable developers to make content easily using the authoring tools (see Fig. 2 (6)). Content developers and authorized people gather again and check these contents (see Fig. 2 (7)). If the quality requirements are not met, the content developers modify the content (see Fig. 2 (8)). In this process, making storyboards as in Fig. 2 (3) is like authoring as in Fig. 2 (6) because they both define how 3DCG models are shown at every state of content. Therefore, we propose an automated content-generation method using storyboards.

2.3 Storyboard specifications

The people authorized generally reach agreements using storyboards when they would like to make 3DCG-based training content like movies. These storyboards do not have a specific format. Handwriting and a combination of text, figures, and pictures are used to make storyboards. Our idea is to utilize storyboards to determine the content specifications and to automatically generate actual content. Fig. 3 shows an example of storyboards for maintenance training content made with PowerPoint software, which is commonly used in many companies. The upper figure in Fig. 3 shows a page of the storyboard. The induction text in Fig. 3 (1) is written in the title area of PowerPoint. 3DCG models are shown as pictures (see Fig. 3 (2)). The ignition device and dryer are shown as pictures, and these pictures are grouped with text format figures. This text names the parts of the devices and corresponds with actual 3DCG models when the storyboard file is imported into the authoring tool. Therefore, the sizes, positions, and rotations of grouped pictures in PowerPoint do not affect actual generated content. Actual action is defined as text format figures (see Fig. 3 (3)). In this example, the action "move forward +x" is grouped with an ignition device (see Fig. 3 (4)). The page expresses that the ignition device moves forward in the +x direction. The movement distance is a fixed value. The global coordinates are shown in Fig. 3 (5). The coordinates are a reference for content developers.

The lower figure in Fig. 3 is part of actual storyboards. 50–70 slides are used for training content.

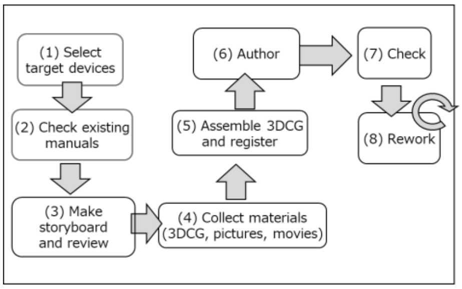

Fig. 2 Process for making maintenance training content.

2.4 Generating contents automatically from storyboards

Fig. 4 shows the system configuration of maintenance training content automatically generated from storyboards. White squares are features of the existing authoring tool. Colored squares are the unique features of this research. All content should be generated by a PC. A keyboard, a mouse, and a touch panel are used for input. The data storage in Fig. 6 stores 3DCG objects, images, and movies for generating content. Generated content is stored in JavaScript Object Notation (JSON) format. Developers can verify this generated content with the tool.

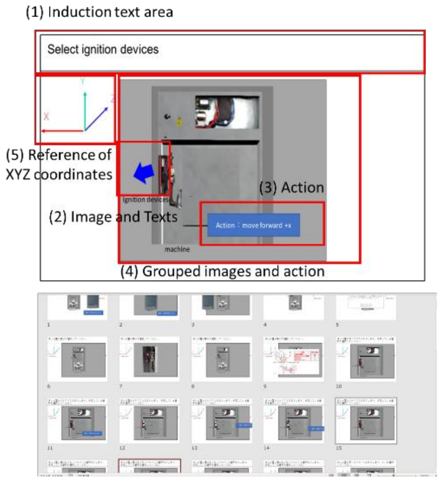

Fig. 3 Example of content design on PowerPoint (top) and some storyboards (bottom).

The more information included in storyboards, the easier it is to automatically generate content. However, the burden of understanding such complex storyboards increases for developers. Therefore, storyboards should be simplified like Fig. 3 (top). We introduce two features for meeting this requirement.

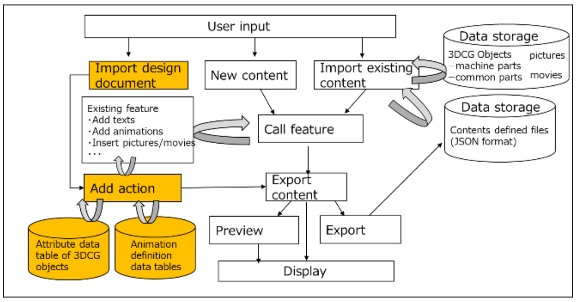

Fig. 4 System configuration of authoring tool with feature of automatically generating contents.

(1) Attribute table for 3DCG objects

The authoring tool has attribute tables that manage each position, rotation, and scale. In this research, each part has three new attributes. All elements are shown in Table 1. The first new attribute is the movement direction. Some parts have a set movement direction when they are defined on storyboards.

The second new attribute is the rotating axis. All the parts have a unique rotation center and axis, as shown in Fig. 5. For example, the center of the torque driver in Fig. 5 is at the top. The driver rotates along the axis. The center of the dryer door in Fig. 5 is centered at its rotation axis.

The third new attribute is the type. Each part has an attribute like “common parts” or “machine parts.” Examples of “common parts” are screws, drivers, wrenches, etc. “Machine parts” are the part of machines like the door, the cover, the motor, etc. Fixed movement distances are set for common parts and machine parts. For example, the movement distance for common parts is 0.1. The movement distance for machine parts is 1. A fixed rotation amount is set for common parts and machine parts. For example, the rotation amount for common parts is 4 times 90 degrees. The rotation amount for machine parts is 1 time 45 degrees.

Table. 1 Data configuration example of 3DCG

File name	Position (x, y, z)			Rotation (x, y, z)			Scale (x, y, z)			Moving direction	Rotating axis	Type
Torxscrew	-0.16	0.88	-0.9	-90	0	0	1.5	1.5	1.5	Z	Z	common parts
Troxdricer	0.16	0.88	-0.8	-90	83	180	2	2	2	Z	Z	common parts
Ignition device	0.21	0.85	-0.7	0	0	0	1	1	1	X	Y	machine parts

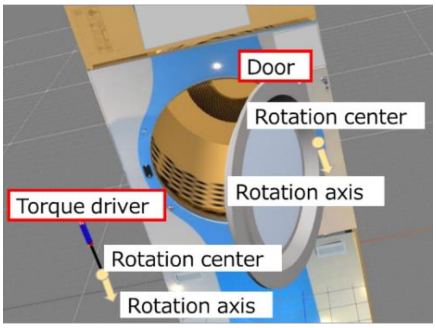

Fig. 5 Examples of rotation center and axis.

(2) Automated generating animation technology based on attribute tables

The authoring tool can generate animations utilizing attribute tables. The configuration is shown in Fig. 6. Each module has a role:

- Display: Show training contents.
- Module for analyzing storyboards: Analyze each page of storyboards and get target names and actions of 3DCG objects.
- Module for analyzing attribute data: Get attribute data of each 3DCG object from attribute data table.
- Attribute data table of 3DCG objects: Manage attributes like position, rotation, scale, rotation axis, and type.
- Module for converting action names into animation data: Get action names from storyboards and convert them into animation definition data.
- Animation definition data table: Manage actual animation functions like moving forward and rotating.
- Module for generating animation: Generate appropriate animation data for target 3DCG object’s attributes like movement direction, rotating axis, type, and action.

The feature generates move forward and rotation animation. The former animation is generated from the movement direction and part type. The movement distance is determined from the part type. The latter animation is generated from the rotation axis and part type. The rotation amount is also determined from the part type.

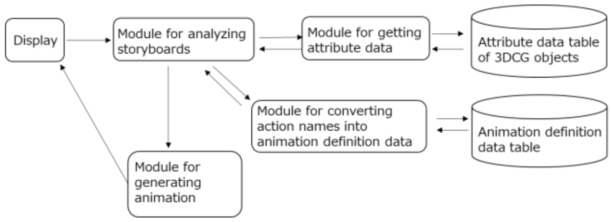

Fig. 6 Software configuration for automated animation generation method.

Fig. 7 (a) shows an example storyboard. It shows a forward movement animation of an ignition device from a dryer. Fig. 7 (b) shows content generated by an authoring tool from the storyboard. The XYZ coordinates are shown on the left side of Fig. 7 (a) and (b). The “ignition device” picture in Fig. 7 (a) corresponds with the “ignition device” 3DCG model in Fig. 7 (b). The “Action: move forward -z direction” in Fig. 7 (a) corresponds with actual animation in the authoring tool in Fig. 7 (b). The blue circle in Fig. 7 (b) shows the start position of the ignition device model. The blue dot arrow in Fig. 7 (b) shows movement in the “-z” direction.

All the training content sizes of the 3DCG model are equal to real spaces, meaning that 1 movement distance is equal to 1 meter. The size of the ignition device in Fig. 7 is approximately 20 square cm. The movement distance of the ignition device is 1 meter because it is a machine part type. Because users of the training content feel that it moves too much in the 3DCG world, the movement distance should be modified by content developers after automated generation.

3 Experiments

We examined cost-cutting effects using our automated content generating method. Seven people participated in the experiment. All the participants had a similar skill level in making content. We divided them into two groups. Group A participants used an existing authoring tool to make training content. Group B participants used our authoring tool with the automated content-generation method. They both executed three tasks. The first task was making storyboards. The target content was disassembling a dryer and extracting an ignition device. They made the content while referring to actual content. There were 50 storyboards. The second task was authoring content. Group A participants used the existing authoring tool and referred to their storyboards. Group B participants used the automated content generating method and modified part of it manually. The third task was modifying content. We chose a person with high-level skills for making training content to be the grader. He graded all the content from the participants and pointed out insufficient expressions. We timed all the participants in the three tasks.

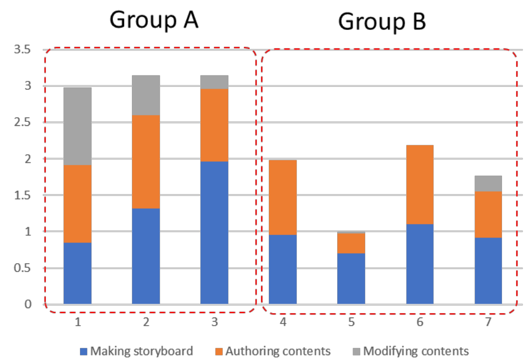

Fig. 8 Experiment results between intermediate authoring skills.

Fig. 8 shows experiment results between Groups A and B. Participants No. 1–3 belonged to Group A, and participants No. 4–6 belonged to Group B. All data was normalized by participant No. 5. Reduction rates were calculated from the average cost of both groups. The results shown in Table 2 indicate that our proposal reduces the cost of making content by at least 40%.

4 Discussion

We also gathered opinions from content developers and managers. They found the automatic generation from storyboards to be advantageous. Even people who were not good at 3DCG commented they could use it. However, some action expressions made it difficult to understand what kind of animation would be generated. We should consider improving how we express action in storyboards.

Table 2 Cost and reduction rate of making content

(1) Average cost of Group A	3.09
(2) Average cost of Group B	1.73
(3) Reduction rate (= ((1)- (2)) / (1))	0.44

Our proposal is useful for developing the training content of various models and devices. Content developers can use it easily if they know how to operate PowerPoint.

5 Conclusion

We proposed a method of generating storyboard-based content. Our method utilizes the attribute table of each 3DCG object. The storyboard defines the action of each machine part and common part. These attribute tables and definitions automatically generate content from the storyboard. A trial with seven examinees showed that the reduction cost was over 40% compared with an existing authoring method.

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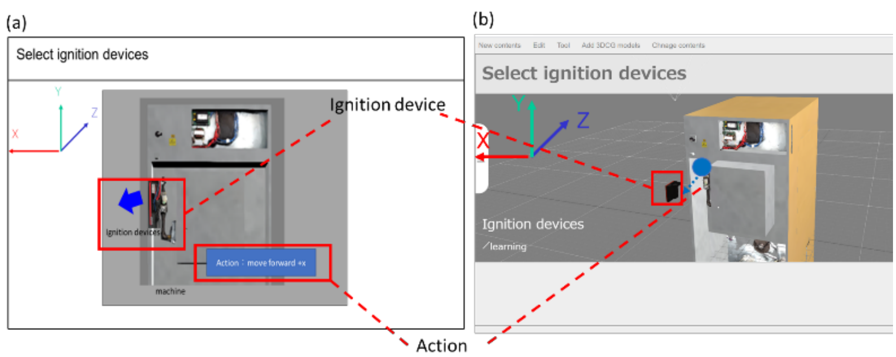

Fig. 7 Example storyboard (a) and generated results in authoring tool (b).