Specification of Daily-Life Objects Places for "Tidy-Up" Robotic Service

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Abstract. In this paper, we focus on the "Tidy-up" robotic service which needs extremely complex and enormous kinds of knowledge about objects, environments, places, and user's status. Especially, we have tried to find the way for specifying of appropriate places of daily-life objects for the "Tidy-up" robotic service. As the first phase, we categorized daily-life objects into three categories: Trashable, Reusable, and Washable. In the specification of an appropriate place, there are two methods: object category based and individual object trajectory based. For the first method, object state machine has been provided for each object category. In the second method, the object trajectories in term of places have been collected. Based on these historical trajectories, we could recognize the trajectory pattern and use it to provide and appropriate place for individual object.

1 Introduction

In this research, we are working on the "Tidy-up" robotic service. Especially, we have tried to find the way for specification of appropriate places of daily-life objects for the "Tidy-up" robotic service. Comparing with "Bring something" service [1] which can be delivered straightforward process, "going to the object's place" → "fetch the objects" → "return to the user's place". However, in "Tidy-up" service, robot needs to decide the way depending on the object's properties, One example is shown in Fig. 1 in which the robot is asked to tidy-up the table. The service requires the robot to perform different tasks with different objects on the table. For example, the books should be brought to bookshelf for storing, and the noodle cup and disposable chopstick should be brought to the trash bin. We have defined three categories of objects that are necessary for the "Tidy-up" service, namely Trashable, Reusable, and Washable. These categories will help to identify the tasks that robot need to do with each object during a "Tidy-up" service scenario. Reusable objects can be returned to their storage area after each use. Washable objects are needed to be washed before returning to storage area. Trashable objects can be trash of directly. The main issue in this research is how automatically specify the appropriate place for each object. In this paper, we propose to use daily-life object properties including categories, usage status and trajectory in term of real-time and historical information to decide and specify an appropriate place for object.

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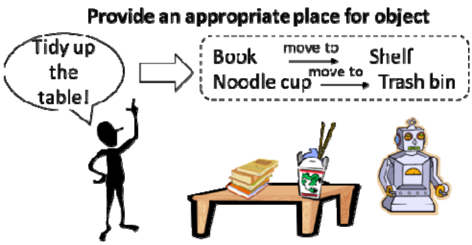

Fig. 1. Example of "Tidy-up" Robotic Service

2 Daily-Life Object Information Management

To provide an appropriate place for "Tidy-up" service, object categories, object usage status and trajectory information is needed. In [2, 3], we proposed a daily-life object information management system to collect, preprocessing and manage the necessary systematically. It has five parts: hardware, software, applications, server and database.

- *Hardware*: RFID reader, RFID tag, ultrasonic transmitter and ultrasonic Receiver attached to receive object ID, object position and usage status information and send it to software layer.
- *Software:* Object information management system has four main modules: object events detection, positioning, and usage status detection and object identification. These modules provide preprocessing raw data that receive from the hardware module then send processed data to the applications layer.
- *Applications:* Appropriate place specification module with object usage status and object position information, this application provided an appropriate place for storing an object or the place to do the next required task. For example, the system will suggest the storing place for the book when we finished read it or suggest the kitchen for used dishes when we finished having lunch.
- *Server & Database:* Server is the center for collecting and processing the data. The database has been used to collect and built the trajectory log.

3 Appropriate Place Specification

Appropriate place specification is a service which automatically provides an appropriate place for individual object based on object current status, place and object type. For the first method, object state machine has been provided for each category of object. In the second method, the object trajectories in term of places have been collected in term of historical data. Based on these historical trajectories, we could recognize the trajectory pattern and use it to provide and appropriate place for individual object.

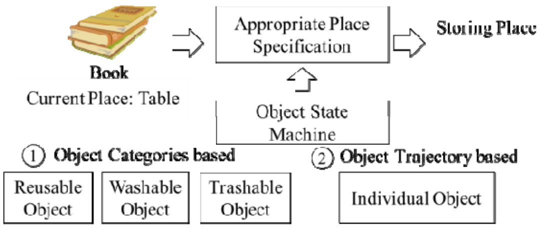

Fig. 2. Appropriate Place Specification Overview

3.1 Object State Machine for Each Category

In this paper, object state machine in terms of place is realized. The following will explain object state machine in detail for each object type.

- **Reusable Object:** A reusable object is an object, equipment or tools in daily life that we can use more than one times e.g. remote control, cell phone. The states of reusable object is most straightforward and have only two state *"Current Place"* After finished the object, or user request appropriate place, the object state change to *"Storing Place"*. Moreover, after the object moved to the *"Storing Place",* it could be moved to other *"Storing Place"*. Fig. 3a) shows a general state machine of reusable object.
- **Washable Object:** A washable object is an object which could be/ need to be washed e.g. Cup, dish, and towel. The state of washable object consists of "*Current Place*", "*Washing Place*" where represents the place for washing the object, and *"Storing Place"* where represents the place for storing an object. Fig. 3b) shows a general state machine of washable object. The object might be moved to "*Washing Place*" and then moved to "*Storing Place*" or skipped "*Washing Place*" and go to "*Storing Place*" directly.
- **Trashable Object** A trashable object is an object that could be trash. The state of trashable object consists of "*Current Place*", "*Storing Place*" where represents the place for storing the object, and "*Trashing Place*" where represents a place for trashing an object. Fig. 3c) shows a general state machine of trashable object.

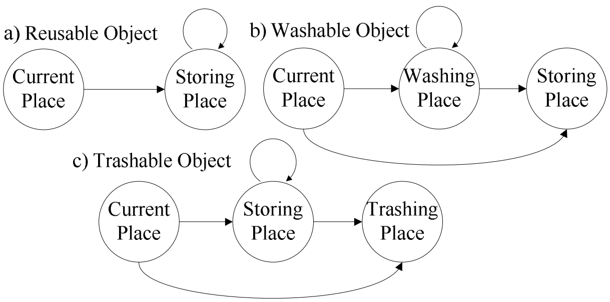

Fig. 3. State Machine of Washable Object

3.2 Object State Machine for Individual Object

In the previous method, we have proposed the object state machine depending on object category. However, it is designed for a general. In this method, the individual properties of the object e.g. trajectory information will be emphasized and used for providing a specific object state machine for individual object. To reduce the effort of collecting the trajectory in a real environment from many participants, the questionnaire approach has been used to ask and collect the real behavior when the users tidy-up the object in the real environment. PrefixSpan [3] algorithm has been used to extract and mining sequential pattern from the answer of the participant. At last, the object state machine for an individual can be build. Fig. 4 shows overview of object state machine building.

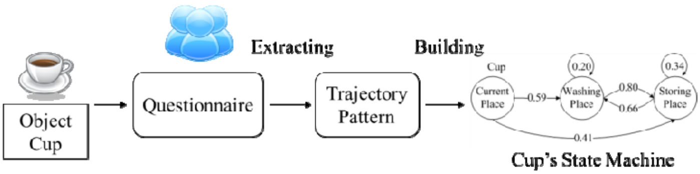

Fig. 4. Building of Object State Machine Overview

1. "Tidy-up" Questionnaire

A questionnaire about "*how users tidy-up the object in a real situation*" has been conducted. As shown in Fig. 5, the questionnaire show the object which put on the table and ask the participant to provide a sequential of place for tidy-up. Participants are freely to choose the sequential of place at from one to three places. The results from questionnaires are the object trajectory and related places. For example in Fig.5, trajectory of the cup from this participant is start from table to dishwasher, sink and finally at shelf; Cup trajectory = table → dishwasher → sink → shelf.

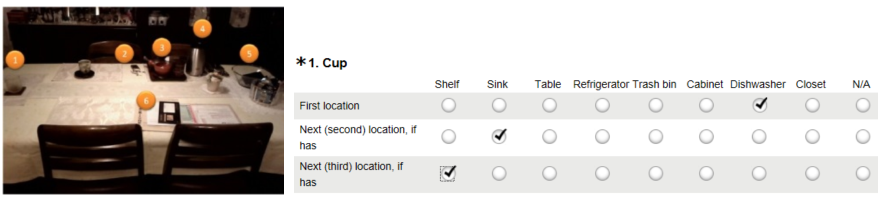

Fig. 5. Example of "Tidy-up" Questionnaire of Cup

2. Extracting Trajectory Pattern

In the second step, the object trajectory of each user will be collect and combined. Using PrefixSpan algorithm [3] we could get the sequential of object trajectory and number of support.

3. Building Individual Object State Machine

In this step, the object state machine would be constructing based on extracting sequential pattern. The places would be merging together based on the place type. Shelf, Table, Refrigerator, Cabinet and Closet are "*Storing Place*", Sink and Dishwasher are "*Washing Place*", and Trash bin is *"Trashing Place"*. For example, sequential pattern Table → Sink, Table → Dishwasher is Table → Washable Place, so we could merge and combine it together. Applying this approach to the entire sequential pattern, we will able to build the object state machine including the transition probability as shown in Fig. 6.

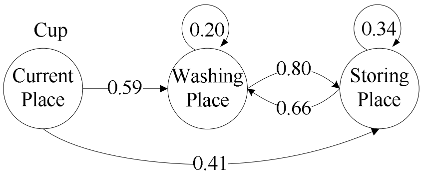

Fig. 6. Object State Machine of Object Cup

4 Conclusion and Future Work

In this paper, we proposed an appropriate place specification method for "Tidy-up" service. We have categorized daily-life objects into three categories namely Trashable, Reusable, and Washable. In the specification of an appropriate place, there are two methods: For the first method, object state machine has been provided for each category of object. In the second method, the object trajectories in term of places have been collected from the questionnaire. Based on these trajectories, we found that the object state machine of individual object was more precise than categories based. It provides a finite state machine including a probability of transition each path. On the others hand, the object state machine for each category describes object state machine in general. The object state machine allows the service robot to know an appropriate place of each object. Our future work will focus on the implementation of "Tidy-up" service in a real experiment with the actual robot system.

References

1. Lam, T.N., Lee, H., Mizukawa, M.: Automatic Building Robot Technology Ontology Based on Basic-Level Knowledge Network. Journal of Roboticsand Mechatronics 23(4), 515–522 (2010)
2. Pei, J., et al.: PrefixSpan: Mining Sequential Patterns Efficiently by Prefix-Projected Pattern Growth. In: Proc. of International Conference of Data Engineering, pp. 215–224 (2001)
3. Skulkittiyut, W., Mizukawa, M.: Daily Life Object Management System in Intelligent Space. In: Third International Conference on Advances in Computer Engineering ACE 2012, pp. 29–34 (June 2012)
4. Mayama, K., Skulkittiyut, W., Ando, Y., Yoshimi, T., Mizukawa, M.: Proposal of object management system for applying to existing object storage furniture. In: 2011 IEEE/SICE International Symposium on System Integration (SII), December 20-22, pp. 279–282 (2011)