

# A Study of Laundry Tidiness: Laundry State Determination Using Video and 3D Sensors

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**Abstract.** In recent years, housework automation has become popular with the rise of robot technology. However, tidying laundry is still manual. Automation by machine is difficult, because clothing is an irregular complex shape. We thought it can handle the laundry by combining depth information and color image. The purpose of this study is to develop a laundry state determination system. This study define state of laundry by dividing into 4 states, and develop laundry state determination system using RGB image and 3D information. The results of experiment of the proposed method suggest that the system was possible to accurately determination the state of the laundry by using depth information and RGB camera image with Kinect.

**Keywords:** Laundry Tidiness, State Determination, Kinect.

## 1 Introduction

In recent years, housework automation has become popular such as cleaning robot or washing and drying machine, etc. Housework automation reduce user's effort of housework, and provide a free time. Housework definition in long-term care services is classified into cooking, washing, cleaning, shopping, throw out trash, clothing organize and clothing repair. There are some agency or automation service for cooking, washing, cleaning, and shopping. For example, for cooking, microwave oven is common consumer electronics. For washing, washing and drying machine is common too. For cleaning, room cleaning robot like Roomba[1] has become popular. For shopping, shopping at online and get it by courier have become easier. However, tidying laundry which is classified as clothing organize is still manual. Automation by machine is difficult[2-4,6-10], because clothing is an irregular complex shape.

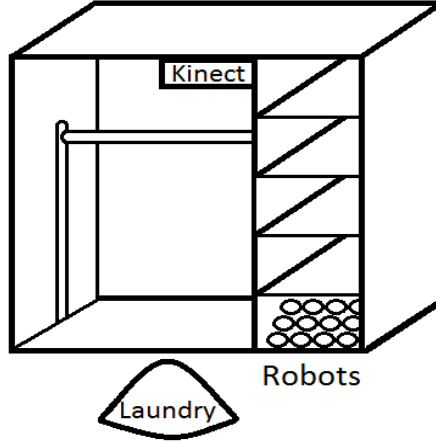
## 2 Automatic Laundry Tidying System

We aims to develop a laundry tidying system of closet type fitted with Kinect (Fig.1). We assume the system as following.

- The system recognized the state of laundry, and gives commands to small robots.
- Small robots can only 3 operations of grabbing, detaching and moving.

- Large clothes such as shirts and pants tidy up by hanging without folding.
- Socks perform a pairing and put away to a particular shelf.

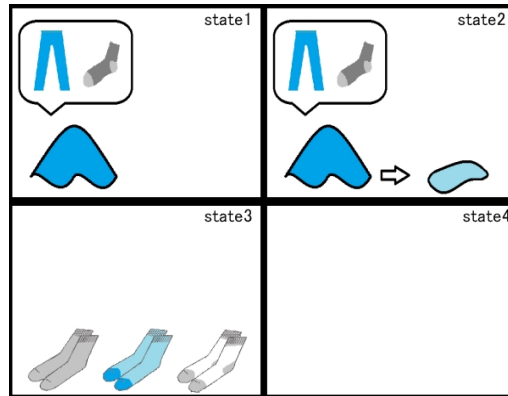
This study is intended to build a system for determining the state of the laundry among the laundry automatic tidying system using depth information and camera image of Kinect[5].



**Fig. 1.** Closet fitted with Kinect

### 3 Definition of Laundry States and Action

We defined the state of laundry in four states as follows. The first state is initial state in which the laundry is placed. The second state is recognized that a laundry was taken out one piece from the laundry pile. The third state is tidying socks which are completed pairing. The fourth state is last state that tidying of laundry is completed. This state is the same as human has finished tidying the laundry, the laundry does not exist on the floor (Fig.2).



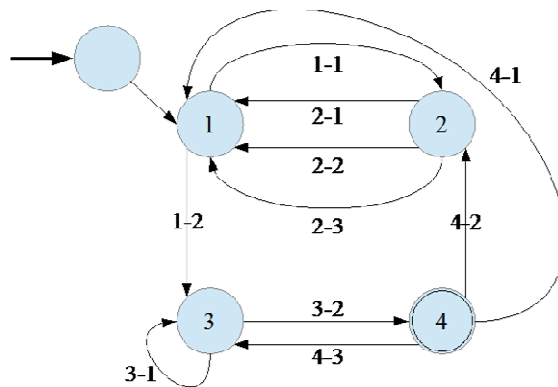
**Fig. 2.** State of the laundry which is divided into four

- state 1: Laundry of all types are mixed, and it is a pile.
- state 2: Laundry is taken out of one piece from laundry pile.
- state 3: Large clothes such as pants are put away. Classification of small clothes which need pairing like socks pairing are complete.
- state 4: Laundry of all has been tidied.

We defined IF-THEN rules of their behavior (Table1). State transition Diagram is as shown in Fig.3. Table1 shows transition of laundry state. "State" is the number of state that laundry state is divided into four parts. "Target" is target which is used determination of laundry state by the system. "IF" is the condition of the "Target". "THEN" is the action when "Target" conforms to the conditions of "IF". "Transition" is transition of laundry state after the action, and transition number of Fig.3. For example, if current state is 1 and the pile of laundry exist, we move a laundry. then current state will transition to state2. In this case, the state transition number is 1-1 in Fig.3. In Fig.3, the starting state is a non-recognition state.

**Table 1.** State Transition

state	Target	IF	THEN	Transition	
1	pile of laundry	exist	object moving process	state2	1-1
	pile of laundry	none	-	state3	1-2
2	recognized object	pants	pants tidying process	state1	2-1
	recognized object	socks	pairing process	state1	2-2
	recognized object	none	-	state1	2-3
3	small clothes	exist	socks tidying process	state3	3-1
	small clothes	none	-	state4	3-2
4	pile of laundry	exist	-	state1	4-1
	recognized object	exist	-	state2	4-2
	small clothes	exist	-	state3	4-3
	all objects	none	-	finished	



**Fig. 3.** State Transition Diagram

## 4 Target Recognition and Determination

The work flow of total process is represented as following 5 sub process.

1. Kinect set the position of 1.5m height downwardly perpendicular to the floor, and initialize Kinect.
2. Laundry pile put on the floor.
3. Recognizes the state of laundry.
4. Acting and Changing the state of laundry.
5. Repeat 3 and 4.

In this paper, we focused on the recognition of IF part. Kinect set downwardly perpendicular to the floor, and a laundry pile put on the camera screen. In addition, Do not put the object of other than laundry on the floor, and to ensure sufficient space for moving laundry. We performed the move of laundry by human operator, not by small robots.

The third process of the above is the most interested in this paper. The details of this process gives as follows.

- Recognizes the state of laundry
  - 3-1. Determination of the recognition field
  - 3-2. If the recognized object is present, apply object recognition
  - 3-3. If threshold less than area of the object is determined to socks
  - 3-4. If threshold above area of the object is determined to pants
  - 3-5. Determination of the laundry pile field
  - 3-6. Determination of the small clothes field
  - 3-7. Decision of the state

The first process is to set Kinect, and initialize using background subtraction for recognize the object. The process performs the following processing.

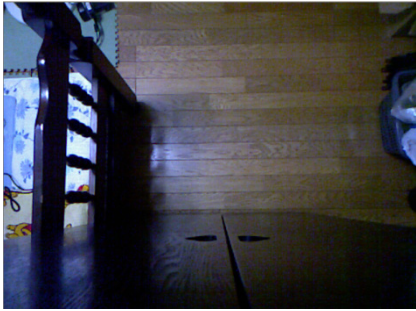
- Initialize Kinect
  - 1-1. Storage of the background image
  - 1-2. Get camera image and a depth of information
  - 1-3. Detection of floor area
  - 1-4. Create of small clothes field to the third upper side of the floor area
  - 1-5. Create of laundry pile field by the rest of third left
  - 1-6. Create of laundry pile field by all remaining

- 1-7. Extraction of laundry by the background difference method
- 1-8. Cut out laundry pile field, recognition field, and the small clothes field
- 1-9. Formed a pile by gathering the laundry in the laundry pile field

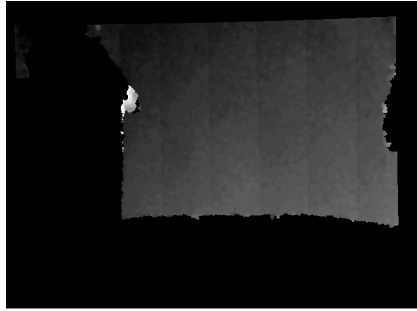
## 5 Experimental

We tested by implementation experimental whether or not Recognition of the IF part is performed correctly. This experiment was performed extracts the information of the laundry using the depth information and the camera image by Kinect. In this experiment use two types of pants and socks as laundry. In addition, threshold of object size is 4000pixel, because we determined to be suitable value for the classification of pants or socks by pre-experiments. And the system was implemented using OpenNI, OpenCV, the VC ++.

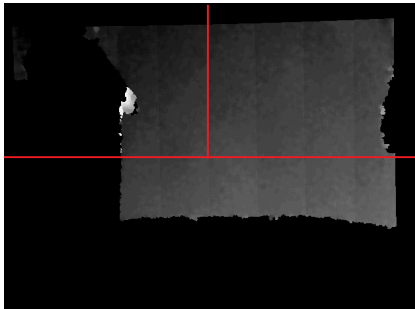
Fig.4 shows a camera image used for background subtraction. Fig.5 shows a depth image that detected the floor area for background subtraction. After aplying initialize Kinect in 1-1 to 1-9, the system correctly cut out laundry pile field, recognized field, and small clothes field. Fig.6 shows a depth image that is divided into three floor area. Fig.7 shows binary image obtained from background subtraction. There is no object so fig.7 is just black. Fig.7 must compare with fig.10.



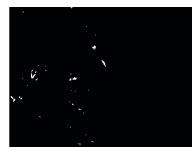
**Fig. 4.** Camera image



**Fig. 5.** Depth image



**Fig. 6.** Devided field image



(a)Recognized field



(b)Laundry pile field



(c)Small clothes field

**Fig. 7.** Binary image obtained from background subtraction

We showed the result of state determination and the transitions of state in Experiment in the following (Table2). Figures 8 to 10 are experimental example images of No.2 in Table2. Recognition of the IF part was able to meet the processing implemented from the experimental results.

Table 2. Results

No	Action	State recognition	Command
1	starting	4	(start)
2	place laundry pile	1	get out
3	socks→recognition field	2	socks pairing
4	socks→small clothes field	1	get out
5	pants→recognition field	2	pants tidying
6	pants→tidying	1	get out
7	socks→recognition field	2	socks pairing
8	socks→small clothes field	3	socks tidying
9	socks→tidying	3	socks tidying
10	socks→tidying	4	(finished)

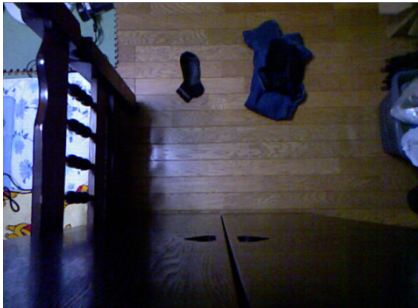


Fig. 8. Camera image of No.2 in Table2

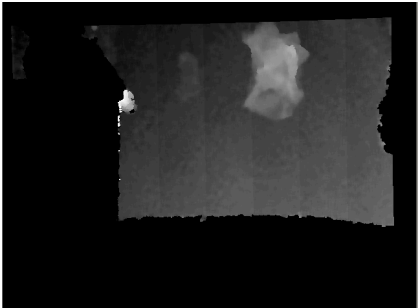


Fig. 9. Depth image of No.2 in Table2

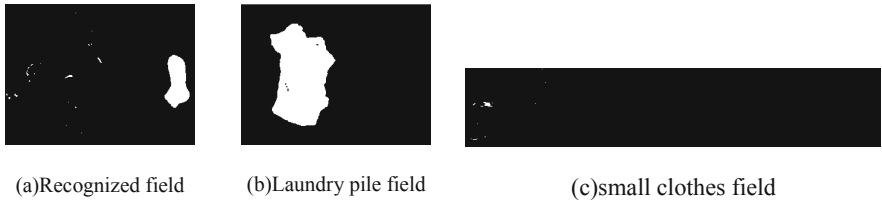


Fig.10. Binary image of No.2 in Table2 obtained from background subtraction

## 6 Conclusion

In this study, we proposed a laundry state determination system using depth information and camera image with Kinect. Results of the implementation experiment of the proposed method, it was possible to accurately determination the state of the laundry.

However, classification by only size must be refined, because type of clothes which need to discern are so many. Therefore, it is necessary to use characteristics such as shape to identify the type of more.

In addition, It is considered that the state determination would be able to do relatively easily because target laundry is limited to pants and socks. Case of assuming home use, it is not able to support at present. Therefore, we push forward with research so as to make accurate state transition by increasing the features to be used for recognition.

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