

# Detection of Unusual Human Activities Based on Behavior Modeling

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# Project Overview

JST/RISTEX **S<sup>3</sup>FIRE** (Service Science, Solutions and Foundation Integrated Research Program)

Project title: **Innovation for Service Space Communication by Voice Tweets in Nursing and Caring**

Aim: To improve working environment in hospitals /nursing homes.

Method: Introducing IT Device: smart voice messaging system (“**Voice Tweet Device**”).

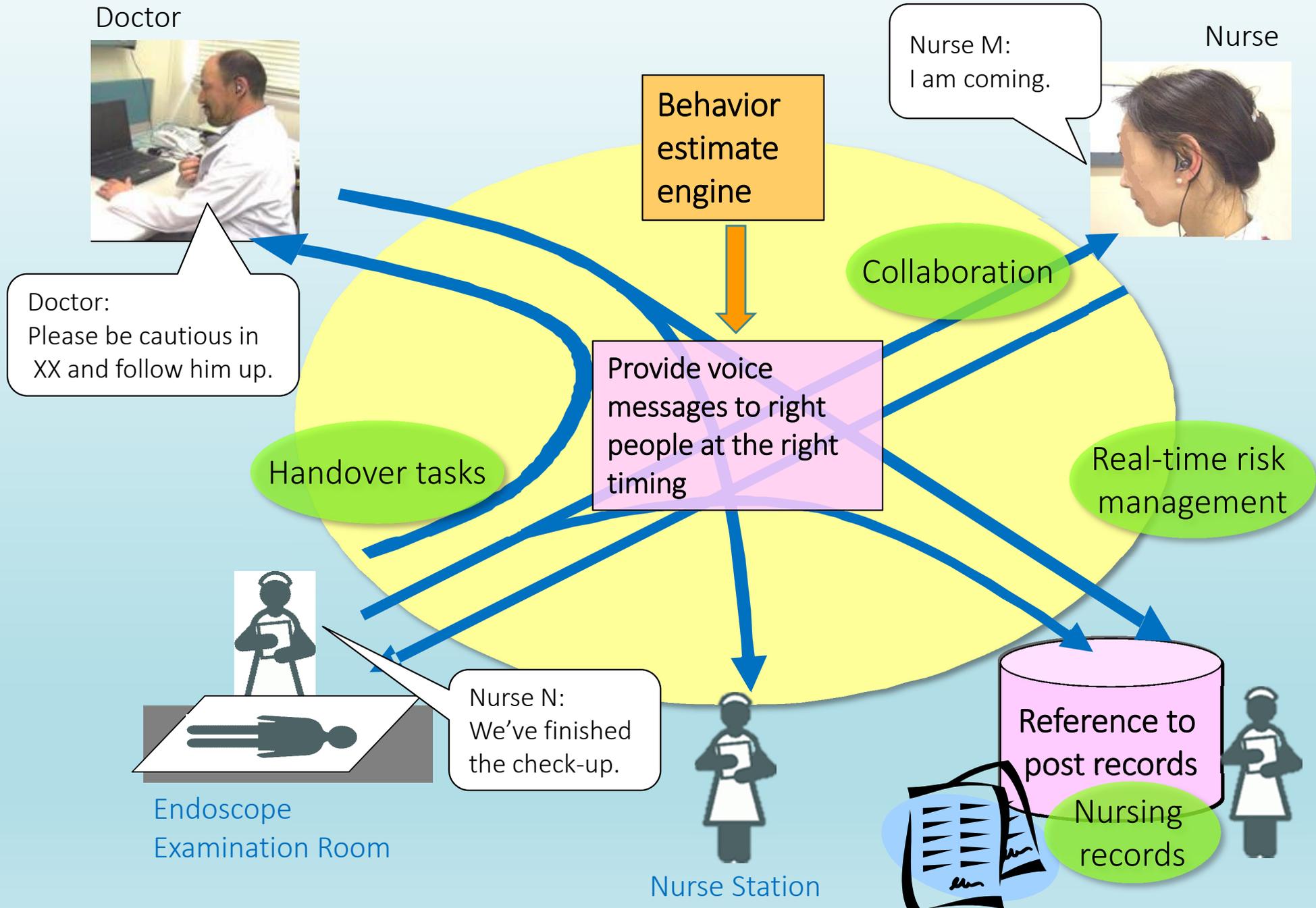
Collaboration between



# The SVM (Smart Voice Messaging) System



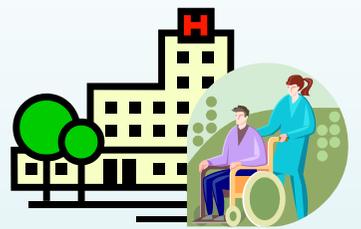
# Smart Message Distribution



# Four Research Groups

- System development and field experiments  
(Toshiba Corp. and all members)
- Visualization/evaluation of space-time communication  
(Shimizu Corp.)
- **Modeling and simulation of human behavior**  
(JAIST Information Science)
- Evaluation of service quality  
(JAIST Knowledge Science)

# Modeling and Simulation Group



Nursing Home (Tokyo)

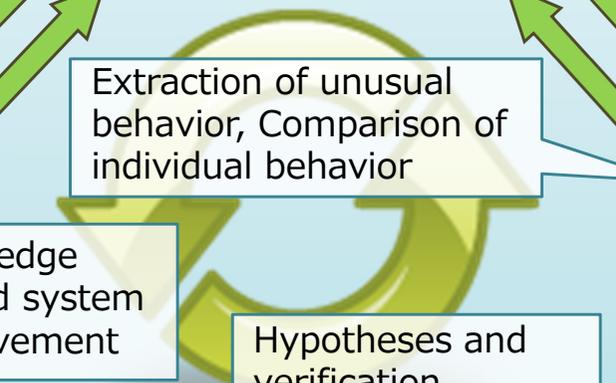
開始	5/25/2014	17:30			
終了	5/25/2014	18:00			
	入室	退室	移動時間(秒)	移動距離(m)	秒
2階2号室	17:30:11	17:30:16	51		0.7
2階2号室	17:30:33	17:30:47	12		0.6
2階2号室	17:30:48	17:31:30			6
2階2号室	17:32:12	17:33:23			12
2階2号室	17:33:24	17:59:18			12
2階2号室	18:00:31	18:00:53			6
1	18:00:54	18:06:16			12
1	18:06:17	18:06:27			35
2階2号室	18:06:28	18:12:01			35
2階2号室	18:12:02	18:12:23			6
2階2号室	18:12:24	18:22:19			12
2階2号室	18:12:24	18:22:19	995	12	1
			0	15	0

Event Log / Voice-message Log

Reproduction of various situation, Iterative experiments under different conditions, prototyping by alternative devices



JAIST (Ishikawa)  
Toshiba (Kanagawa)

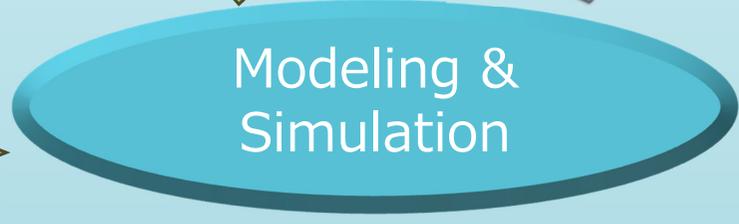


Learning behavior models from logs and their analysis

Extraction of unusual behavior, Comparison of individual behavior

Knowledge toward system improvement

Hypotheses and verification

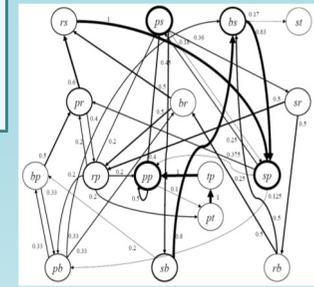


Video

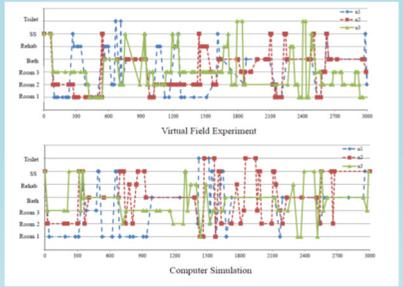
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2階2号室	17:30:48	17:31:30			6
2階2号室	17:32:12	17:33:23			12
2階2号室	17:33:24	17:59:18			12
2階2号室	18:00:31	18:00:53			6
1	18:00:54	18:06:16			12
1	18:06:17	18:06:27			35
2階2号室	18:06:28	18:12:01			35
2階2号室	18:12:02	18:12:23			6
2階2号室	18:12:24	18:22:19			12
2階2号室	18:12:24	18:22:19	995	12	1
			0	15	0

Event Log

Building simulation models from process description, Estimation of behavior models from logs

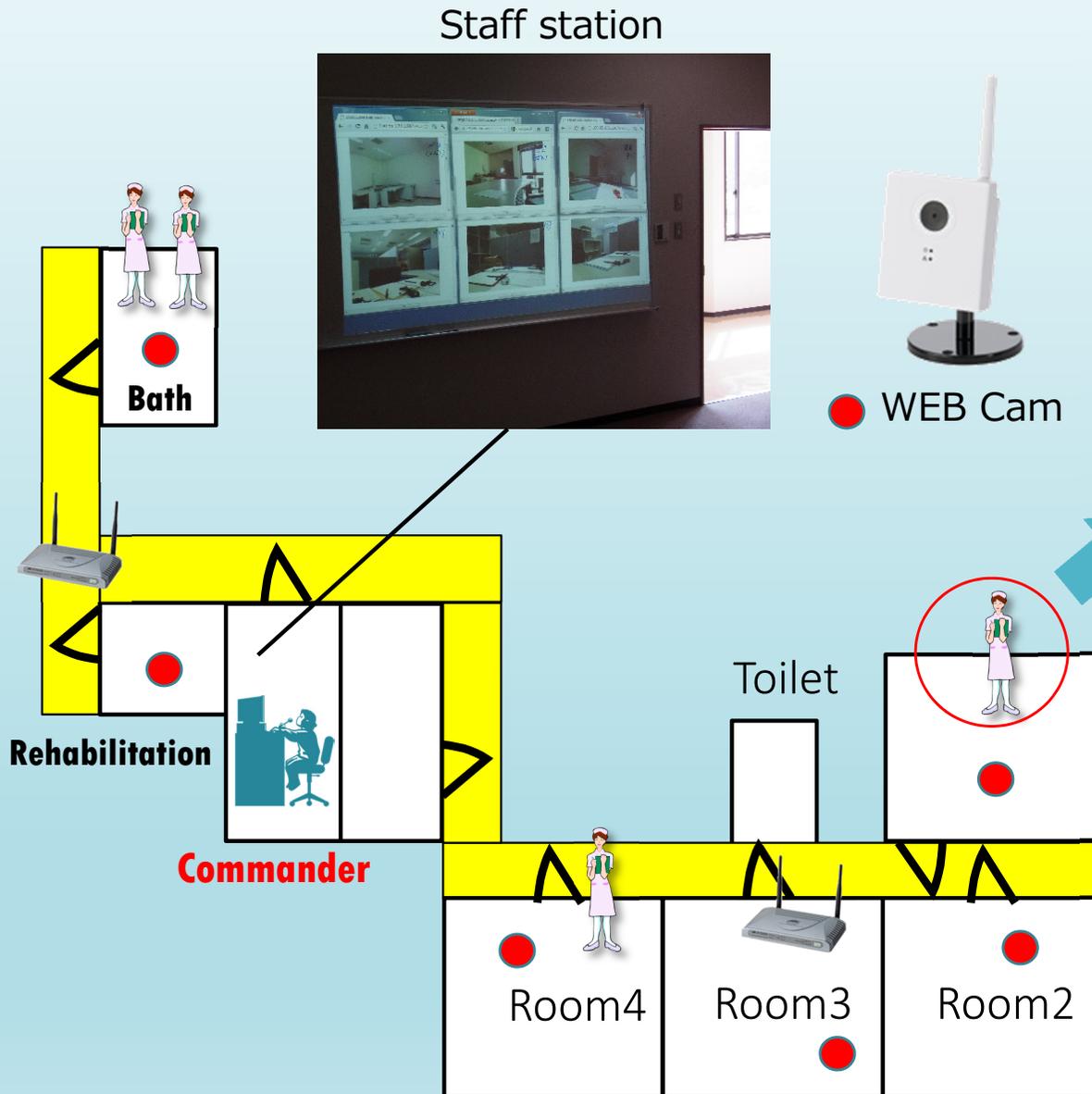


Behavior Model



Traffic Lines

# Virtual Field Experiments



# Results

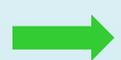
- ▣ We propose formalism for modeling adaptive and cooperative behavior among concurrently acting people.
- ▣ Based on the formalism, we have made behavior models of working staffs in a nursing home.
- ▣ Using the behavior models, human activities of the staffs have been analyzed.

# Formalism: Communicating N-Gram Models

*Conditional Probability*

$Pr(\text{Next Event} \mid \underbrace{[\text{Role}, \text{Situation Mode}] : \text{Event History}}_{\text{attributes}})$

Given by the nurse in charge or other staffs



*Role*

Staff1

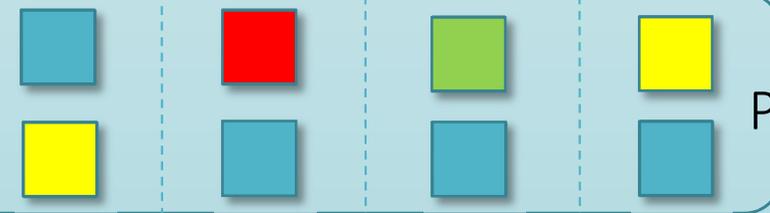
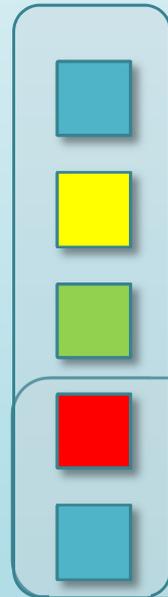
Staff2

Staff3

Staff4

Staff5

*Event History (N-1)-gram*



*Next Event*



*Situation mode*

e.g., the location in which most of the staffs are working

# Learning Models

## Step 1. Event Abstraction

Event format

*(date, Staff-ID, type, in-time, out-time, duration)*

'type' is either the location or "moving".

### Event log

開始	5/25/2013	17:30					
終了	5/25/2013	19:15					
	入室	退室	滞留時間(秒)	移動距離(m)	移動時間(秒)	移動速度(m/秒)	
2FリビングサロンA	17:30:11	17:30:16		5			
↓					12	17	0.7
2FリビングサロンE	17:30:33	17:30:47		14			
↓					0	1	0
2FリビングサロンA	17:30:48	17:31:33		45			
↓					0	39	0
2FリビングサロンA	17:32:12	17:33:23		71			
↓					12	1	12
2FリビングサロンE	17:33:24	17:59:18		1554			
↓					0	73	0
2FリビングサロンA	18:00:31	18:00:53		22			
↓					12	1	12
2FリビングサロンE	18:00:54	18:06:16		322			
↓					35	1	35
208	18:06:17	18:06:27	10				
↓					35	1	35
2FリビングサロンE	18:06:28	18:12:01		333			
↓					0	1	0
2FリビングサロンA	18:12:02	18:12:23		21			
↓					12	1	12
2FリビングサロンE	18:12:24	18:22:19		595			
↓					0	15	0

### Abstraction table

Event	Short stay	Long stay
1F Rooms	a	A
2F Rooms	b	B
3F Rooms	c	C
1F Salon	x	X
2F Salon	y	Y
2F Staff Station	s	S
3F Care Station	z	Z
Moving	-	M
Others (stairs/elevator etc.)	e	E

### Event sequence

bbByyyyyyYyyyyyyyyyybbbbbbbbbbbbbbbyxyyy  
 yyyeMyexaXXXyyyeXXxXxXxxexXXxxeeyxyyyxxM  
 aaXeyY

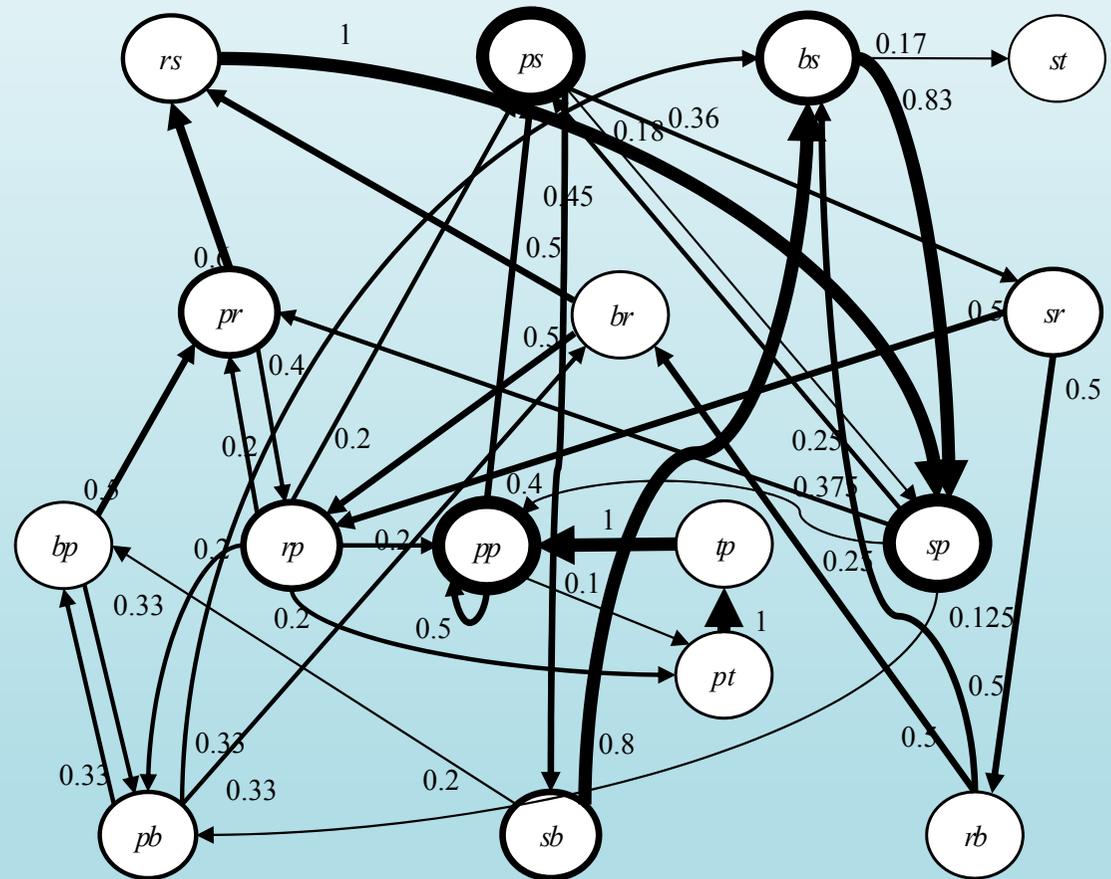
# Learning Models

## Step 2. Maximal Likelihood Estimation of $N$ -gram Model

Event	Symbol
Move to Room1~4	p
Move to Bathroom	b
Move to Rehab. room	r
Move to Staff Station	s
Move to Toilet	t

Conditional probabilities

Prev.	Next	PHS	Tr.I	Tr.II	SVM
<b>br</b>	b	0	0	0	0
	p	0.40	0.67	0.67	0.25
	r	0	0	0	0
	s	0.60	0.333	0.333	0.75
	t	0	0	0	0
<b>pr</b>	b	1.0	0	0.25	0
	p	0	0.67	0.25	0
	r	0	0	0	0
	s	0	0.33	0.05	1.0
	t	0	0	0	0
<b>sb</b>	b	0	0	0	0
	p	1.0	0.20	0.20	0.25
	r	0	0.20	0.40	0.25
	s	0	0.60	0.40	0.50
	t	0	0	0	0



Graphical Representation  
by Probabilistic Automaton

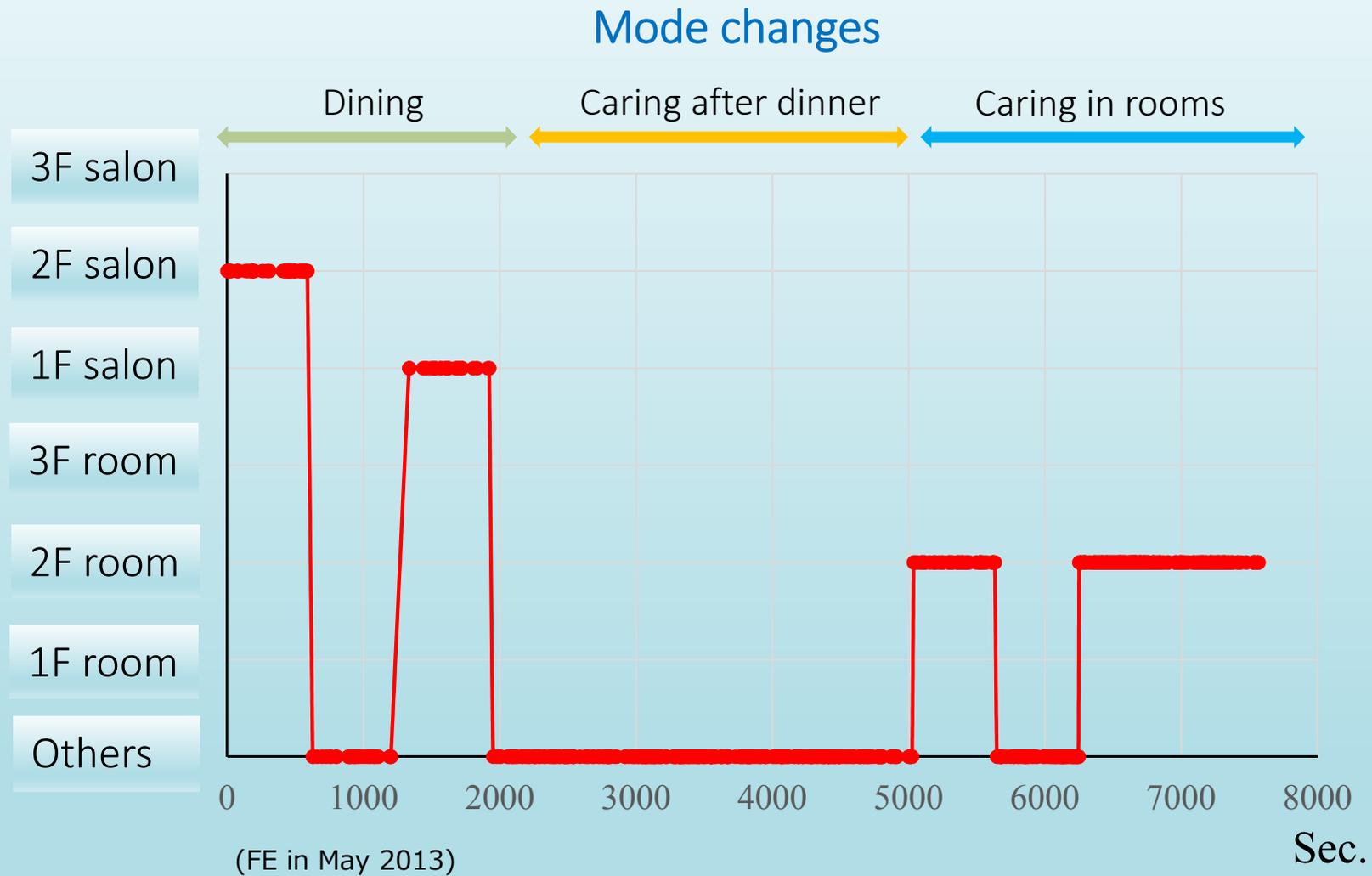
(VFE in Sept. 2012)

# Application to Real Data

The SVM system is tested in a nursing home several times.

- **Field:** In a nursing home with three floors, there are patients' rooms, living salons and other rooms such as a staff station and treatment rooms.
- **Roles of staffs:** In each period of a day, there are around 8 staffs in the field. Each staff has his/her own role, e.g., the in-charge nurse, staffs responsible for 1F/2F/3F, staffs capable of nursing, etc. In the experiments, all staffs carry SVM terminals together with standard equipment.
- **Workflow:** The experiments was done at lunch time and dinner time. At first each staff takes a patient from his/her room to a salon, assists the patient to have a meal, cares for several things after the meal, and finally takes the patient back.

# Result of Estimating Situation mode

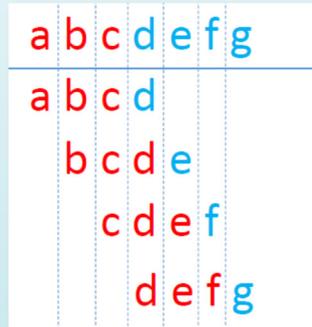


# Analysis: Detection of Unusual/Suspicious Behavior

## Event log

開始	終了	入室	退室	滞留時間(秒)	移動距離(m)	移動時間(秒)	移動速度(m/秒)
17:30:11	17:30:16			5	12	17	0.7
2Fエレベータ	17:30:33	17:30:47		14	0	1	0
1	17:30:48	17:31:33		45	0	39	0
2Fエレベータ	17:32:12	17:33:23		71	12	1	12
1	17:33:24	17:59:18		1554	0	73	0
2Fエレベータ	18:00:31	18:00:53		22	12	1	12
1	18:00:54	18:06:16		322	35	1	35
208	18:06:17	18:06:27		10	35	1	35
2Fエレベータ	18:06:28	18:12:01		333	0	1	0
1	18:12:02	18:12:23		21	12	1	12
2Fエレベータ	18:12:24	18:22:19		595	0	15	0

## Fragments

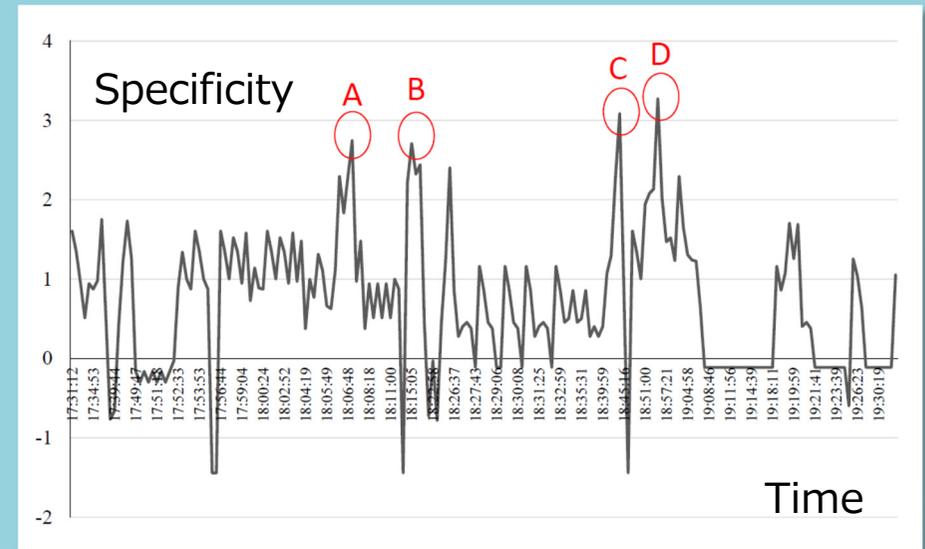


*degree of specificity*

$$= \log \left( \frac{\text{actual occurrences}}{\text{expected number}} \right)$$

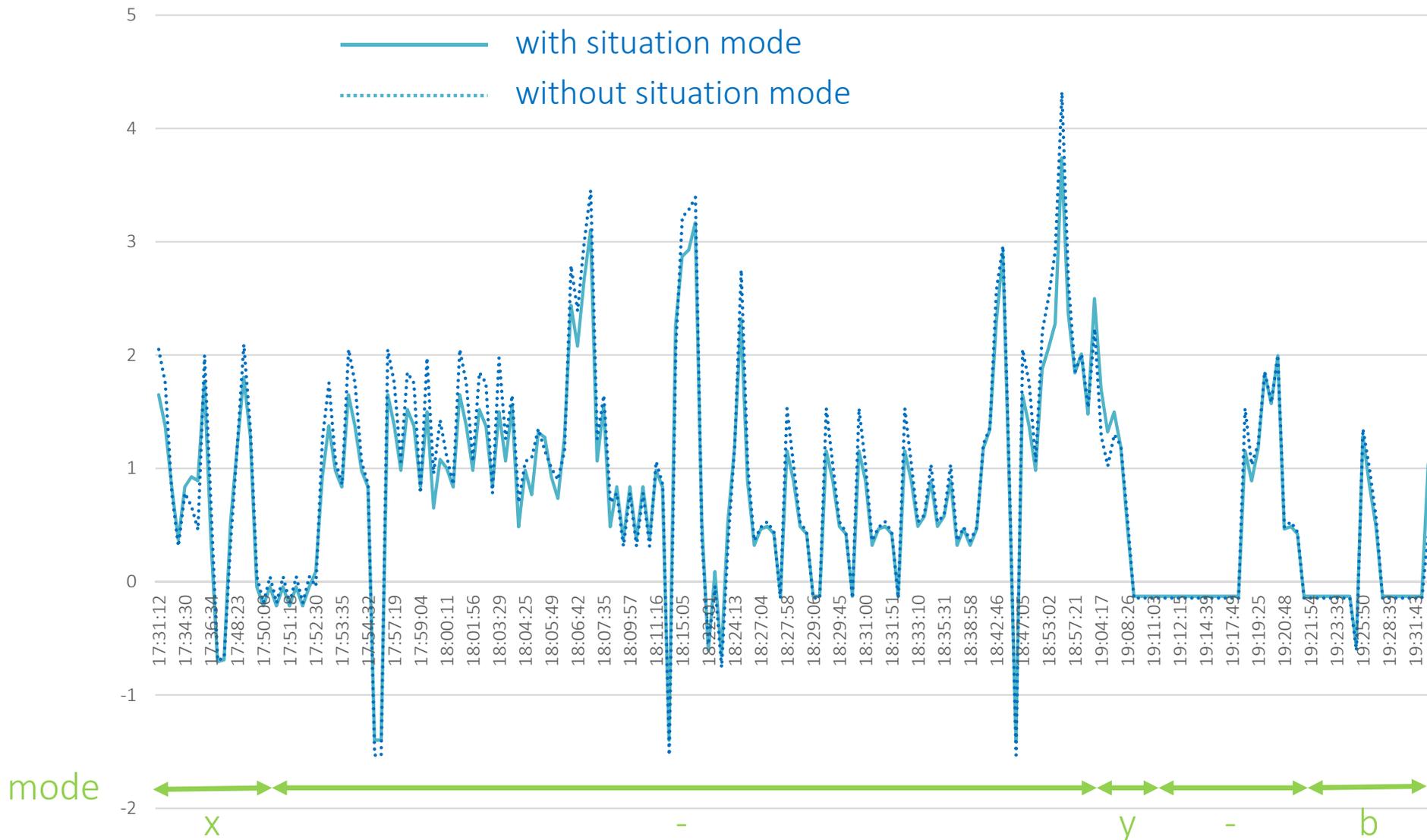
**Behavior model of average behavior**

- A. Frequent movements between different floors: 1F salon → 2F salon → 3F room → 2F room
- B. Long movement and long task at the same location.
- C. The following voice message was sent just before the point: “Ms. XXX has returned to her room by herself. I will go to see her now.” (Usually Ms. XXX needs assistance on her movement.)
- D. Frequent movements using an elevator.



(FE in May 2013)

Such suspicious behavior should be analyzed in the staff meeting.



with/without using situation mode



# Conclusion

Behavior modeling for physical and adaptive intelligent services:

- Learning probabilistic models from event logs,
- Diagnosis of human behavior: detection of unusual/suspicious activities, discrepancy between individual log and average behavior

Ongoing/Future work

- How to utilize the results for improving service quality
- Modeling collaboration of staffs
- More experiments on other fields