Behavior Modeling in Physical and Adaptive Intelligent Services

Kunihiko HIRAISHI, Koichi Kobayashi,
Sunseong Choe, Naoshi Uchihira

School of Information Science,
Japan Advanced Institute of Science and Technology

JAIST

Project Overview

JST/RISTEX S^{3}FIRE (Service Science, Solutions and Foundation Integrated Research Program)

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

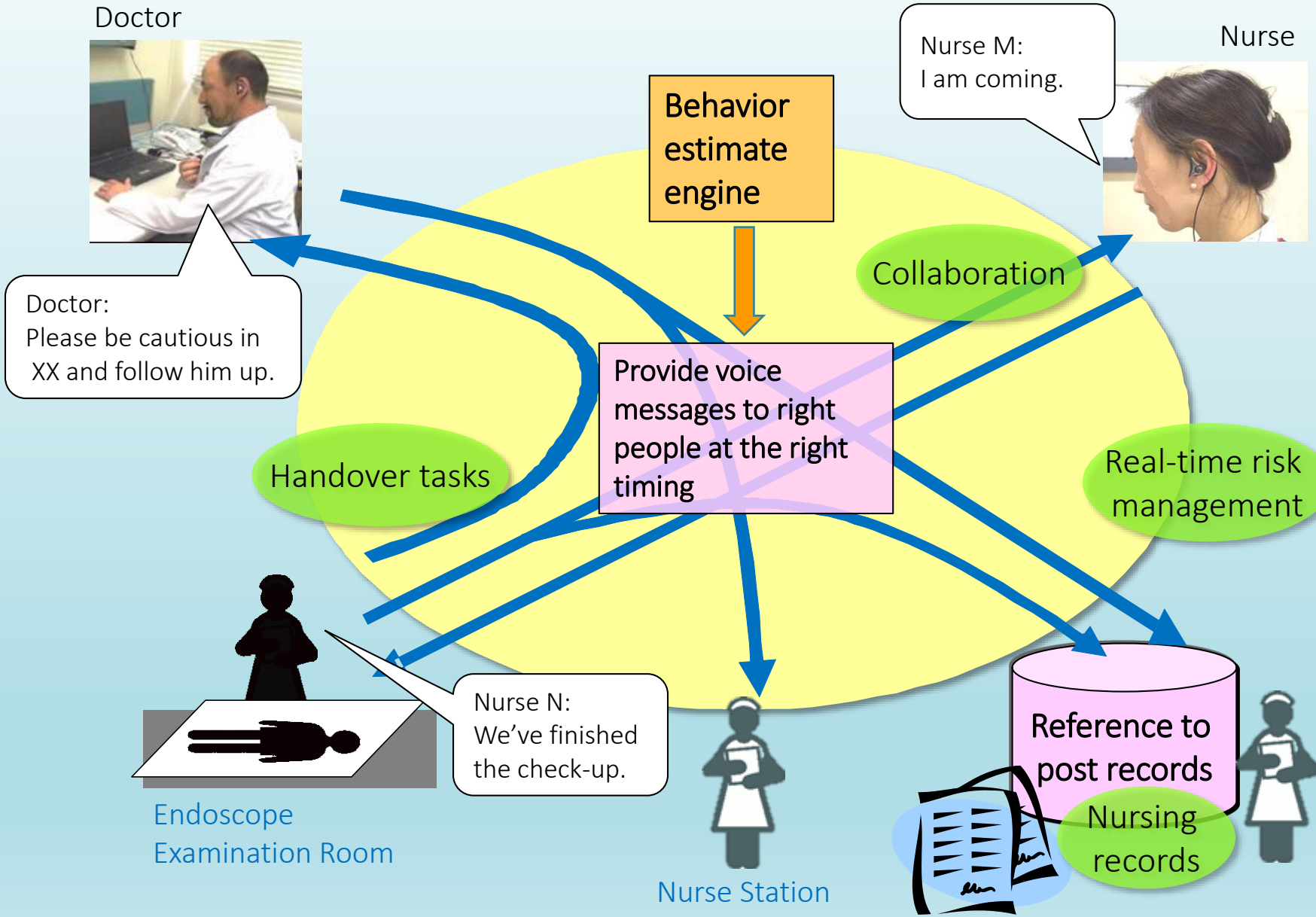
Aim: To improve working environment in hospitals /nursing homes.

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.)

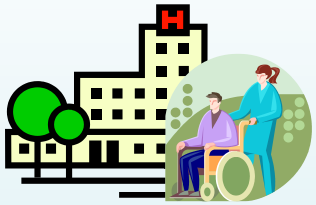
- Modeling and simulation of human behavior

  (JAIST Information Science)

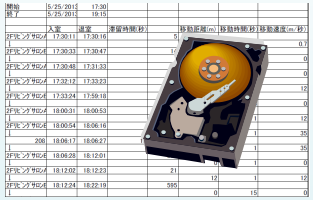
- Evaluation of service quality

  (JAIST Knowledge Science)

Modeling and Simulation Group: Method



Nursing Home (Tokyo)



Event Log / Voice-message Log

Field Experiments

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

JAIST (Ishikawa)
Toshiba (Kanagawa)

Extraction of unusual behavior, Comparison of individual behavior

Learning behavior models from logs and their analysis

Knowledge toward system improvement

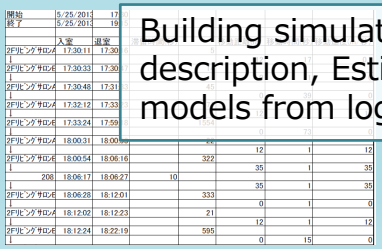
Hypotheses and verification

Virtual Field Experiments

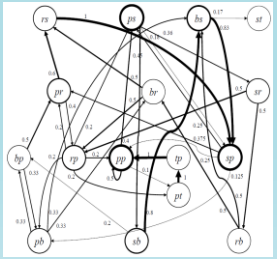
Modeling & Simulation

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

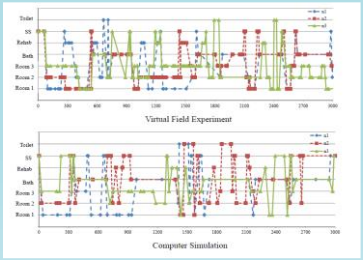
Video



Event Log

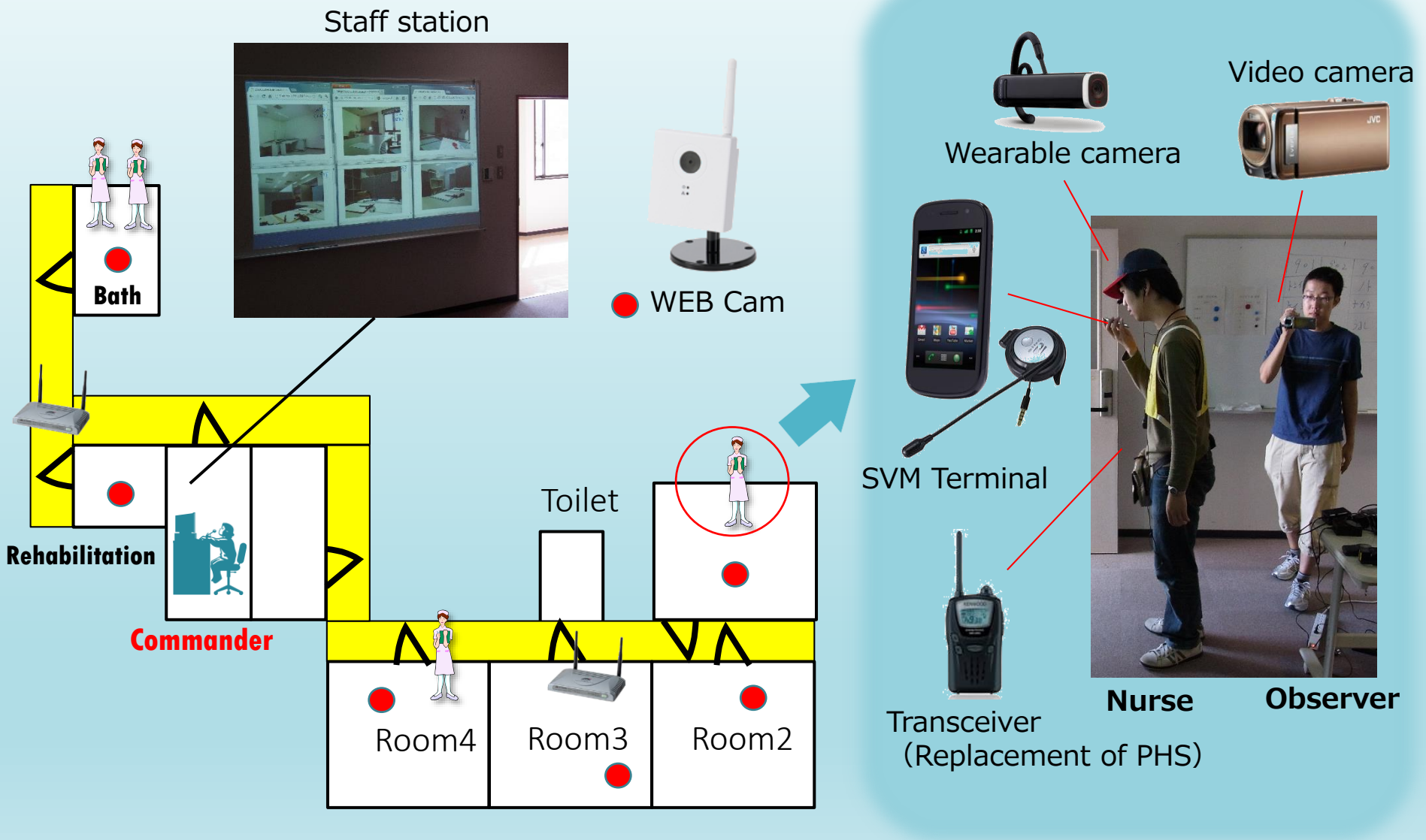


Behavior Model



Traffic Lines

Virtual Field Experiments



Experiments

Virtual Field Experiments

20 December 2011 at JAIST

17 January 2012 at JAIST

13 February 2012 at Toshiba Corp.

13 September 2012 at JAIST

22 February 2013 at JAIST

13-15 March 2013 at Toshiba Corp.

28-29 August 2013 at JAIST

Field Experiments (at a nursing home in Tokyo)

5-8 December 2011

21-24 February 2012

27 September 2012

20-24 May 2013

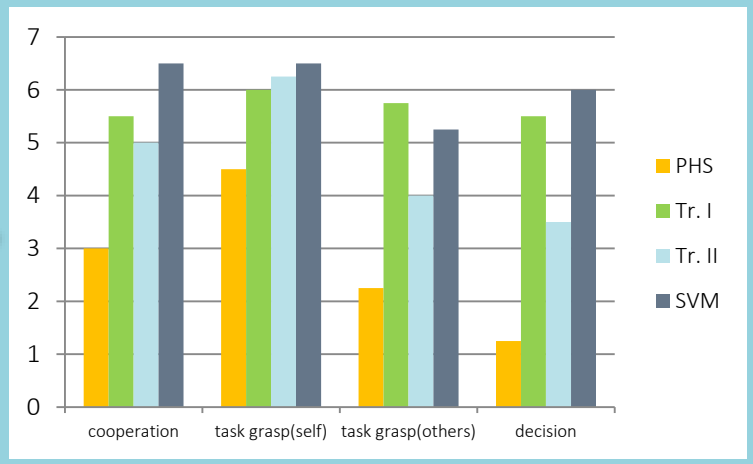
21-23 August 2013

Evaluation of Communication Methods in VFE

- Traditional Approach -

		PHS	Tr. I	Tr.II	SVM
Type	broadcast / one-to-one / one-to-group	to one	BC	BC	to group
Timing	synchronous / asynchronous	Syn	Syn	Syn	Asyn
Report	status reporting of tasks	-	✓	-	✓
	status reporting of other staffs and resources	-	✓	-	✓
Inquiry	to a staff	✓	-	-	✓
	to all	-	-	✓	✓
	about availability of resources	-	-	✓	✓
Request	assistance of tasks	✓	-	✓	✓
Use System data	event history	-	-	-	✓
Device		PHS	Transceiver	Transceiver	SVM

Communication Methods



Result of Questionnaire
(Subjective evaluation)

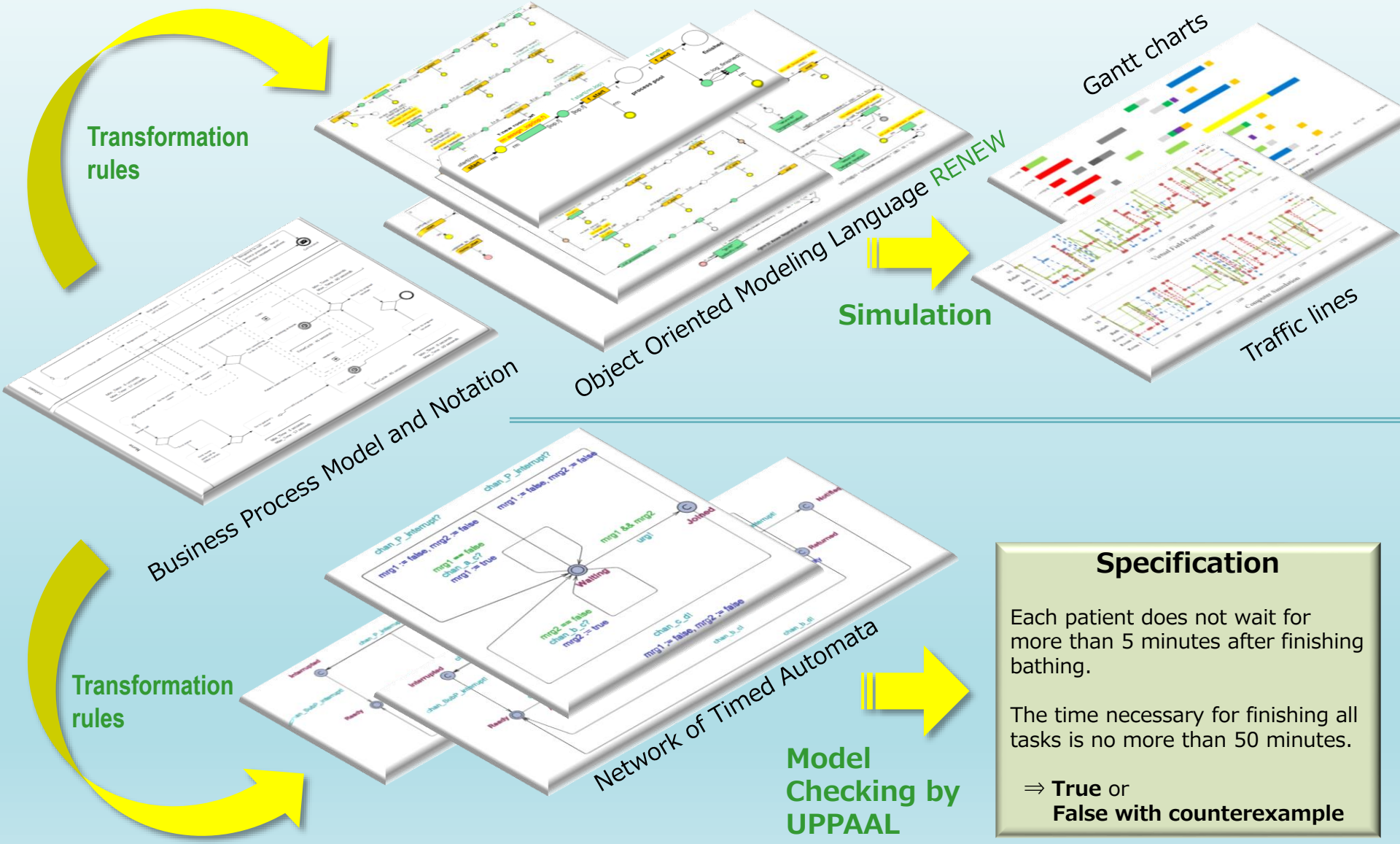
	PHS	Tr.I	Tr.II	SVM
Total	3276.4	3286.59	2639.89	2981.24
Nurse1	1062.29	573.46	802.56	864.98
Nurse2	764.69	953.15	725.43	686.65
Nurse3	801.64	922.49	614.24	649.22
Nurse4	647.78	837.5	497.67	780.4

Length of Traffic Line

	unfinished tasks (sec.)	waiting time (sec.)	NC response AVG (sec.)
PHS	46	26.9	1.5
Tr.I	42	21.4	1.5
Tr.II	56	35.1	1.7
SVM	34	18.6	1.8

Statistics on Time

Automatic Synthesis of Executable Models from Process Description



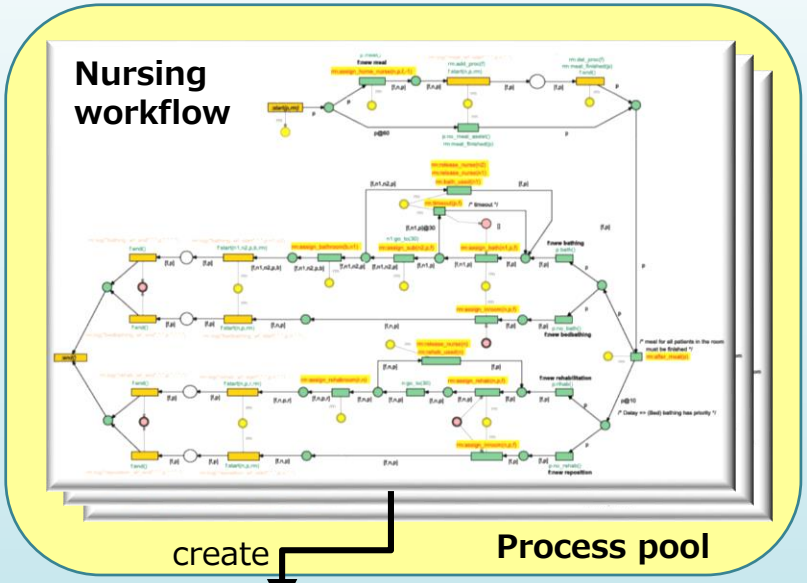
Specification

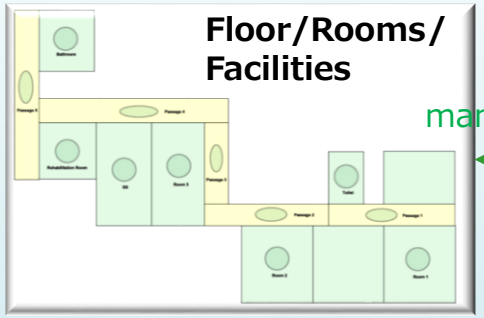
Each patient does not wait for more than 5 minutes after finishing bathing.

The time necessary for finishing all tasks is no more than 50 minutes.

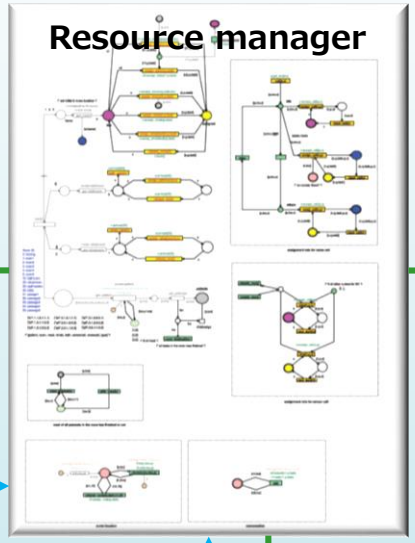
⇒ **True** or
False with counterexample

Structure of RENEW Simulation Model





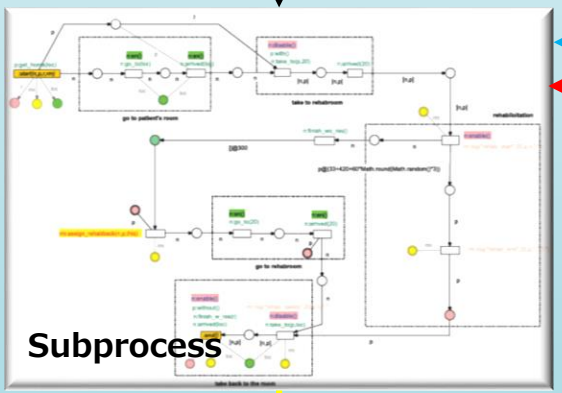
manage



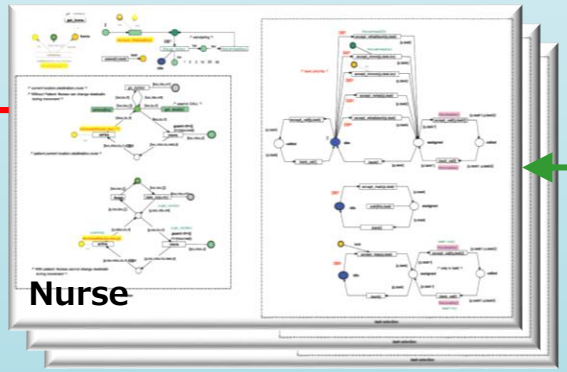
request/assign

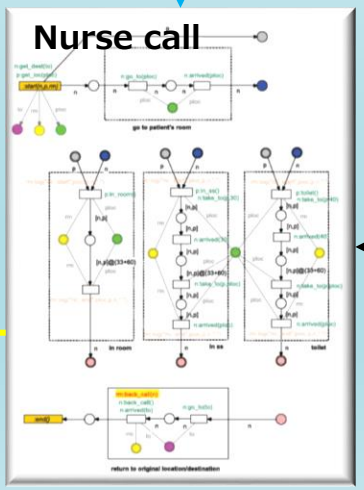
request/assign

manage

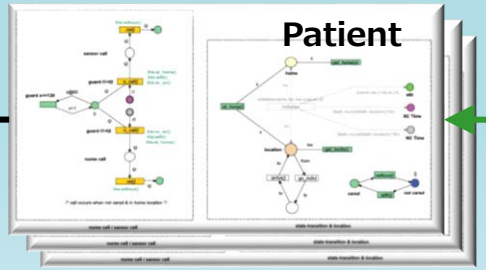


interrupt



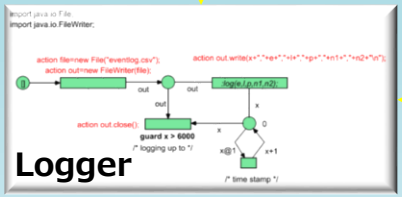


manage



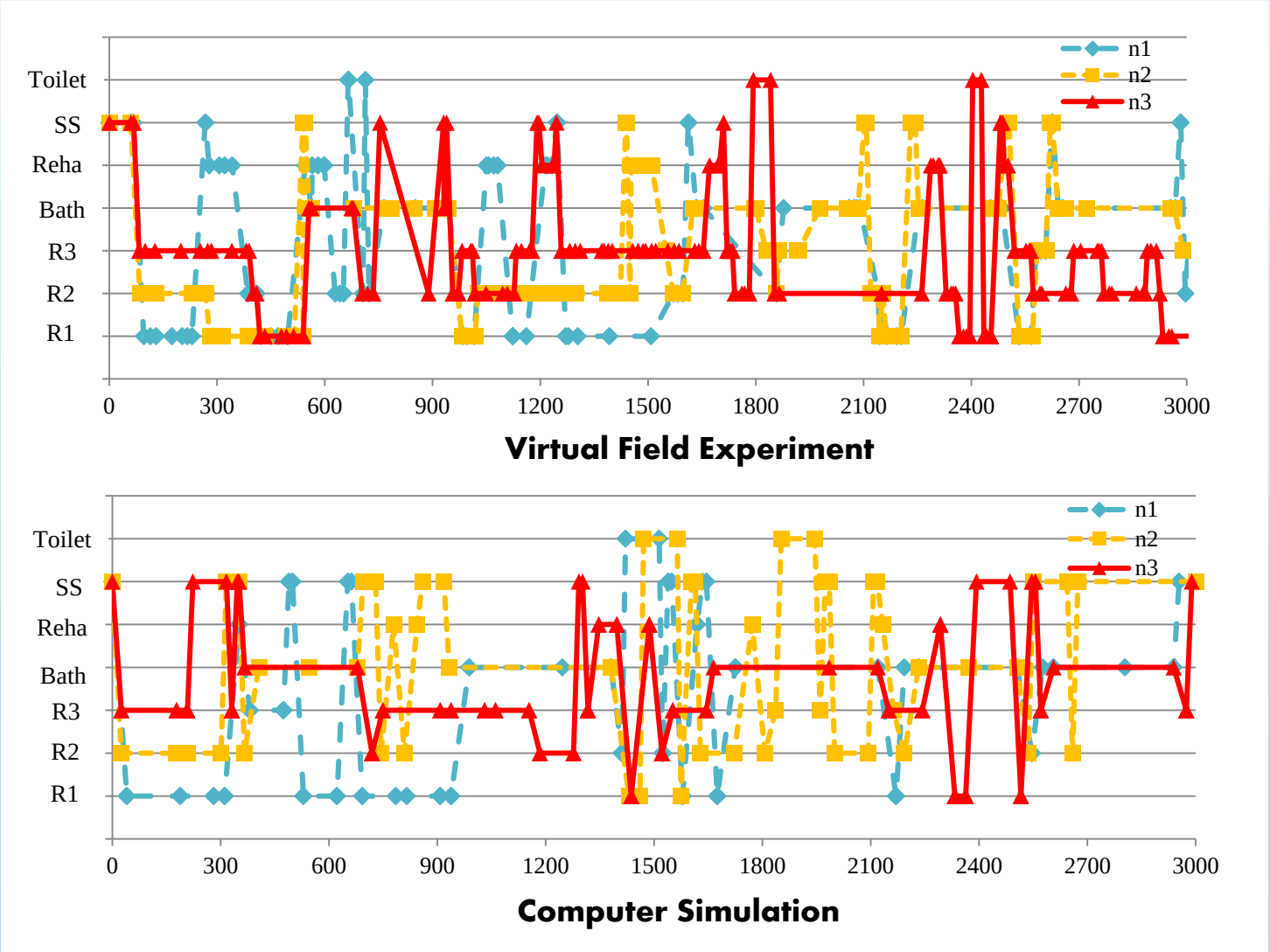
create

event type/time



event type/time

A Result of Simulation – Traffic Line -



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B	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B	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B	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B	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B	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

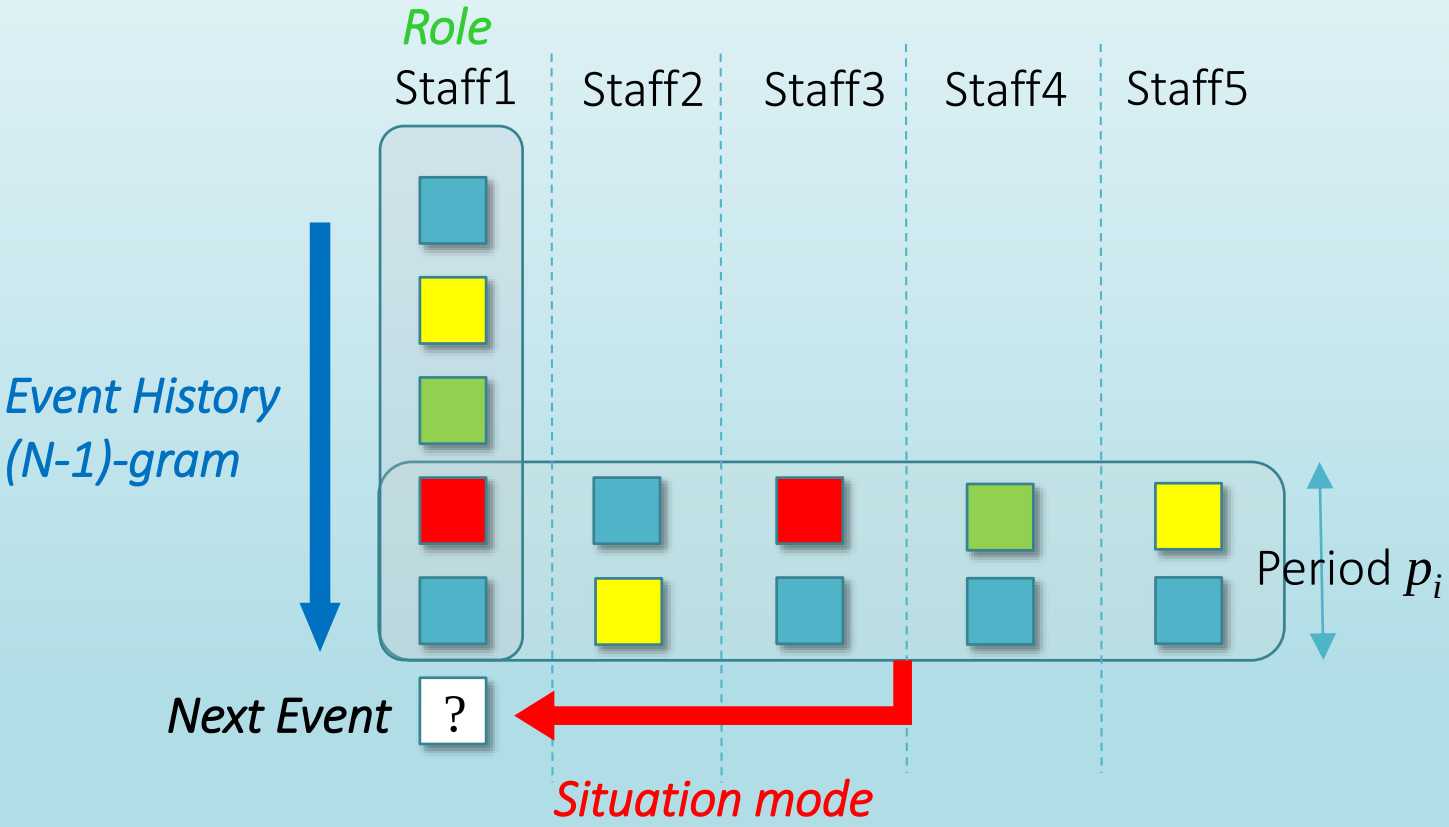
Event sequence

bbByyyyyyYyyyyyyyyyyybbbbbbbbbbbbbbbbbyxyyyyyyeMyexaXXXyyyeXXxXxXxxexXXxxeeyyxyyyyxxMaaXeyY

Step 2. **Modeling: Attributed *N*-Gram Model**

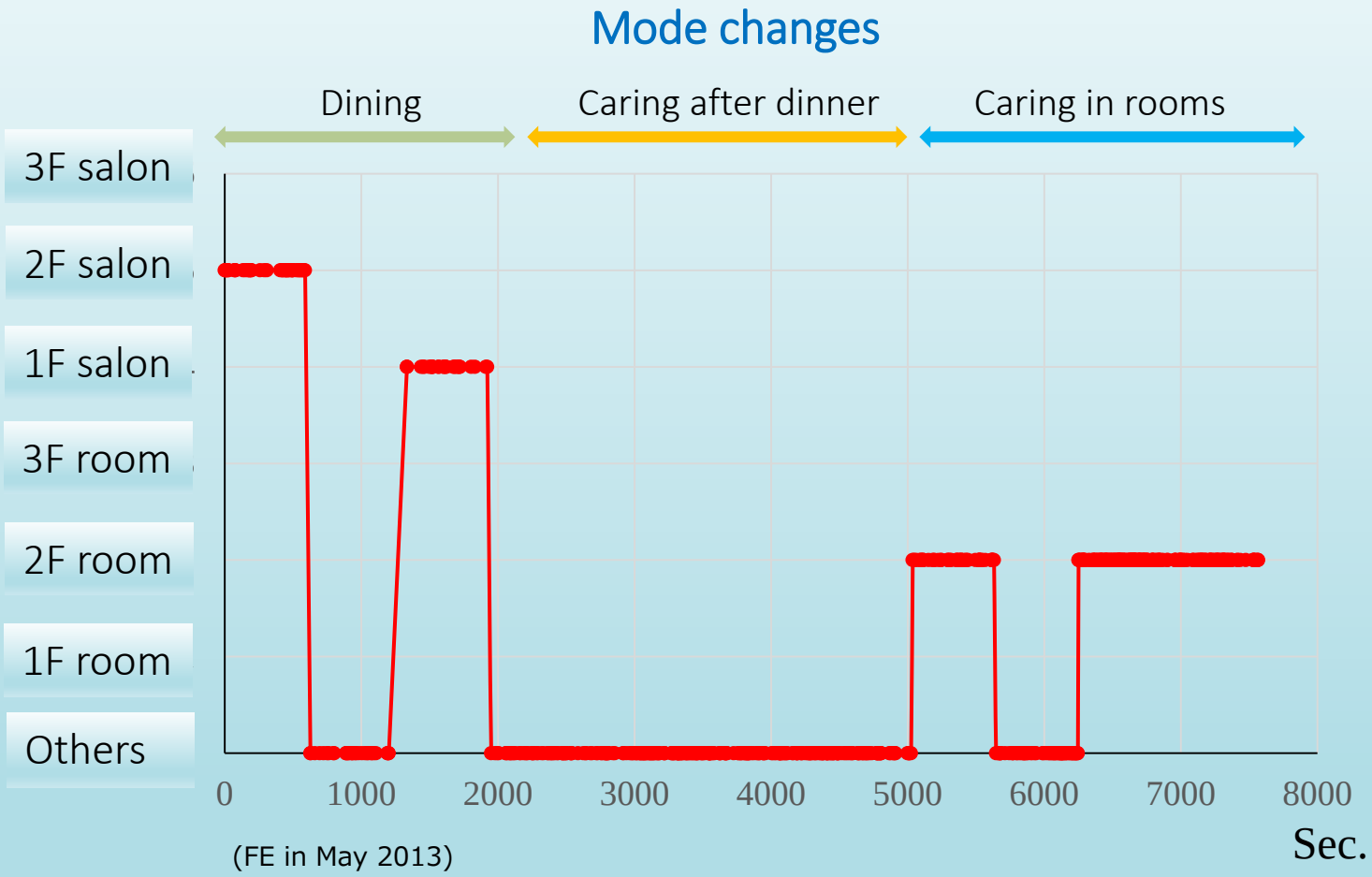
Conditional Probability

Pr(Next Event | [Role, Situation Mode] : Event History)



= the location in which most of the staffs are working

Step 2. **Modeling: Situation mode**



Step 2. **Modeling: Learning Models from Event Logs**

Maximum likelihood estimation

$$Pr(\sigma|y) = \frac{O_{y\sigma}(w)}{\sum_{\sigma' \in \Sigma} O_{y\sigma'}(w)}$$

w: the given event sequence.
$O_s(w)$: the number of times string s occurs in w.

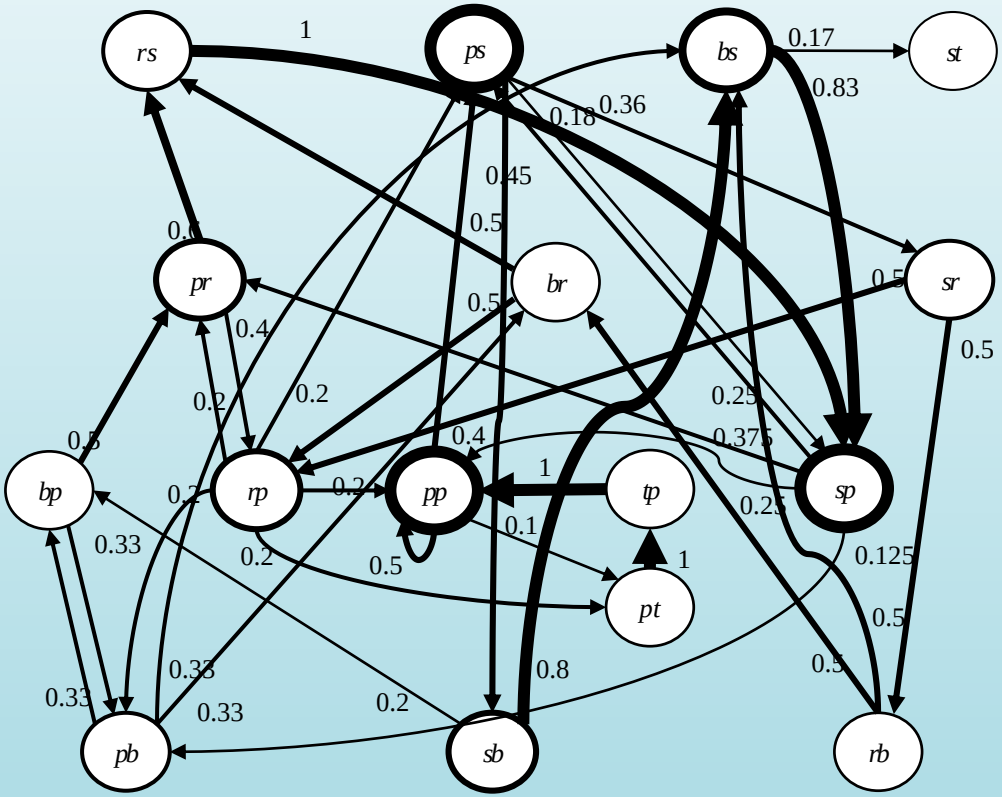
Step 2. **Modeling: Probabilistic Automata**

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
br	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
pr	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
sb	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

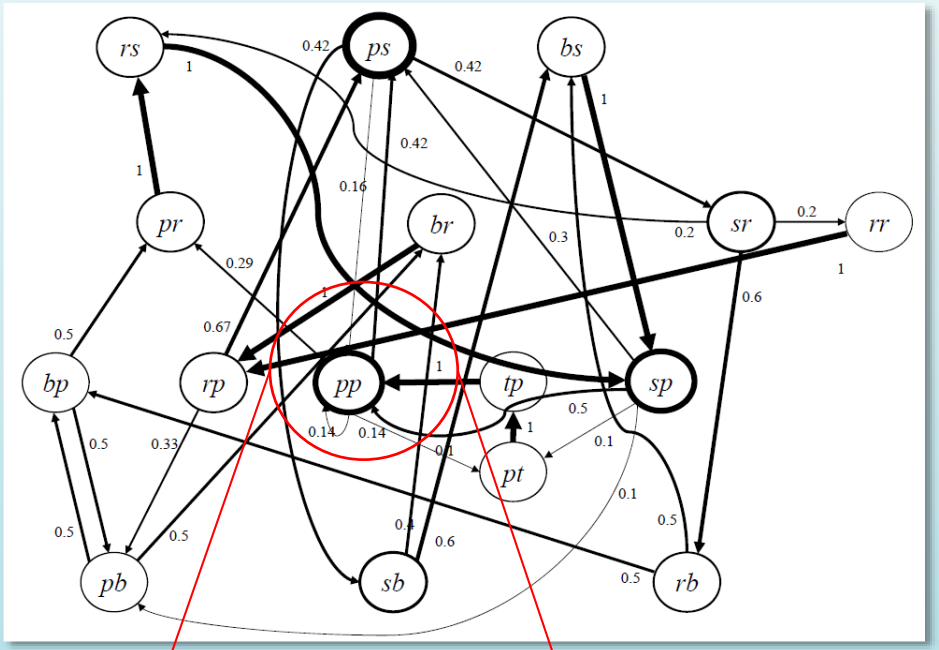
(VFE in Sept. 2012)



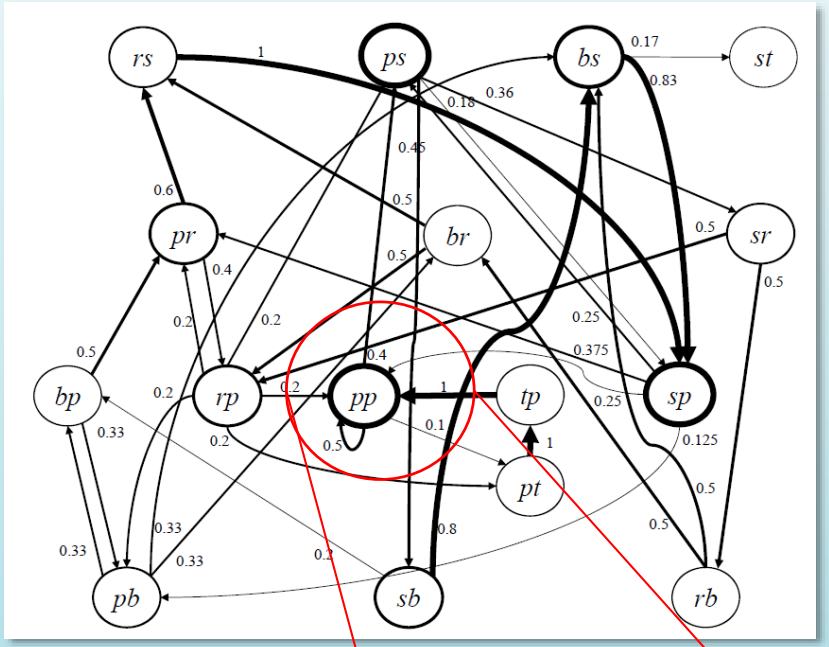
Graphical Representation
by Probabilistic Automaton

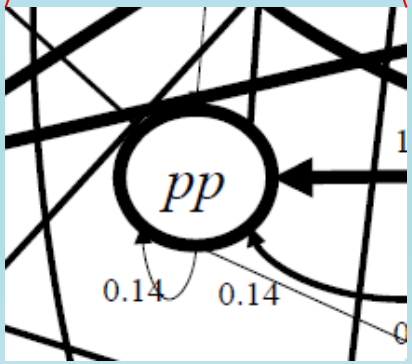
Step 3. **Analysis:**
Comparison of Models in different Situations

Transceiver II



SVM

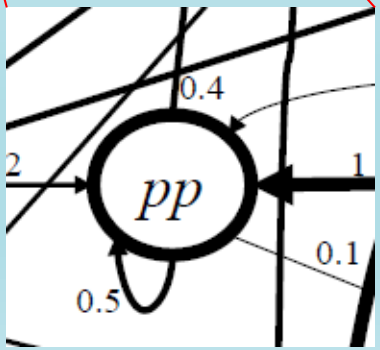




(VFE in Sept. 2012)

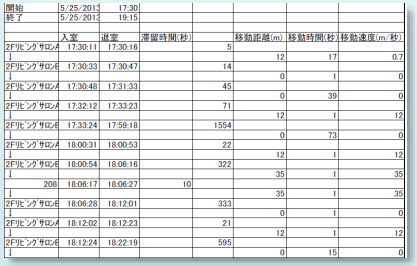
$Pr(Room \mid Room \rightarrow Room)$
= 0.14 (Tr. II), 0.5 (SVM).

In-room tasks were interrupted often in experiments other than SVM.

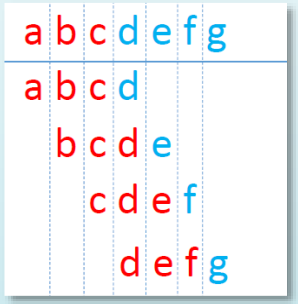


Step 3. **Analysis:**
Detection of Unusual/Suspicious Behavior I

Event log



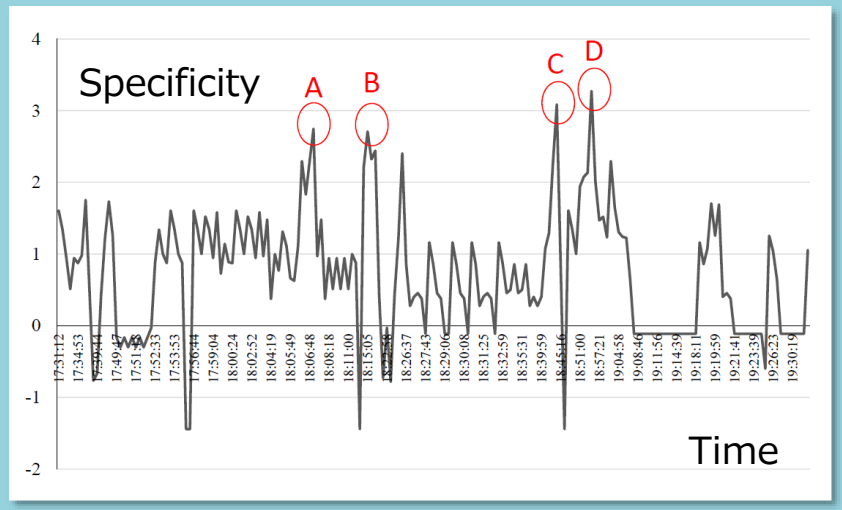
Fragments



$$degree\ of\ specificity = log\left(\frac{actual\ occurrences}{expected\ number}\right)$$

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.

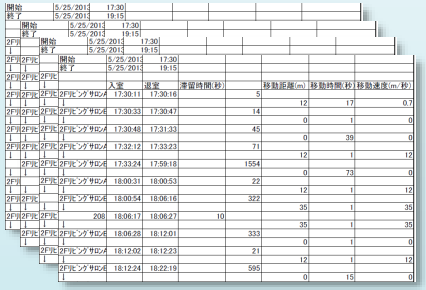


(FE in May 2013)

Time series of specificity

Step 3. **Analysis:**
Detection of Unusual/Suspicious Behavior II

Event log of each staff

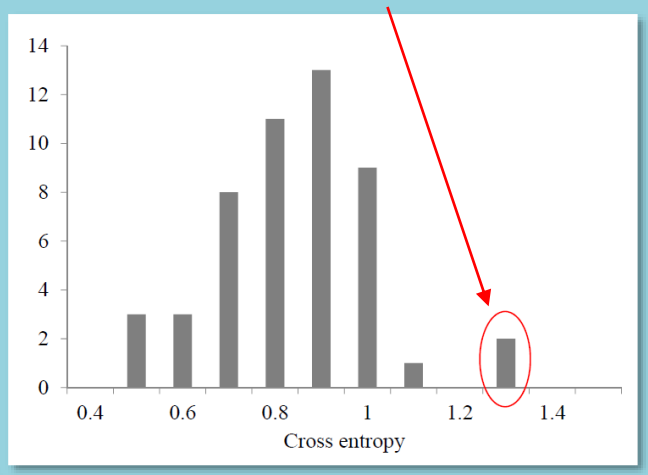


Cross entropy analysis (Discrepancy between log and model)

$$H(w) = -\sum_{j=1,|w|} \frac{1}{|w|} log_2 Pr\left(s(w_{[j]}) | a(w_{[j-N+1,j-1]}) : s(w_{[j-N+1,j-1]})\right)$$

Behavior model of average behavior

Different behavior:
Most of time is spent in 1F salon.



(FE in May 2013)

Histogram

Conclusion

Behavior modeling for physical and adaptive intelligent services:

– Detailed process description,

– Automatic generation of executable models for simulation and verification,

– 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