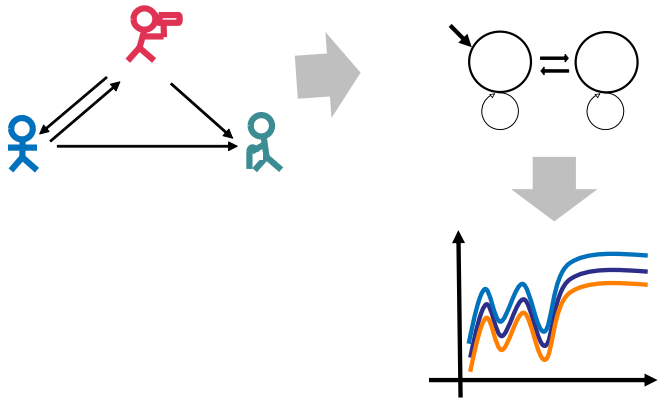
How Should Remote Monitoring Sensor Be Accurate?



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Remote Monitoring of Elderly People

- Many countries are faced with an **aging society**
  - 40% of Japanese become 65 years old or more in 2050
  - Similar statistics in Europe, China, Korea, etc.

- Many elderly people are living alone
  - Growth of the nuclear families
  - Limited number of care givers

- Remote families are concerned, but cannot always look after directly
  - Own job, individual life, economy, etc.

-> Strong needs of **Remote Monitoring Services (RMS)**

Remote Monitoring Service (RMS)

Service that allows a family to monitor remote elderly

- A wide variety of services are on market

Post office

Home Visit Service

- **Home Visit Service (Japan Post Office)**
  - Postman visits the elderly to check the status

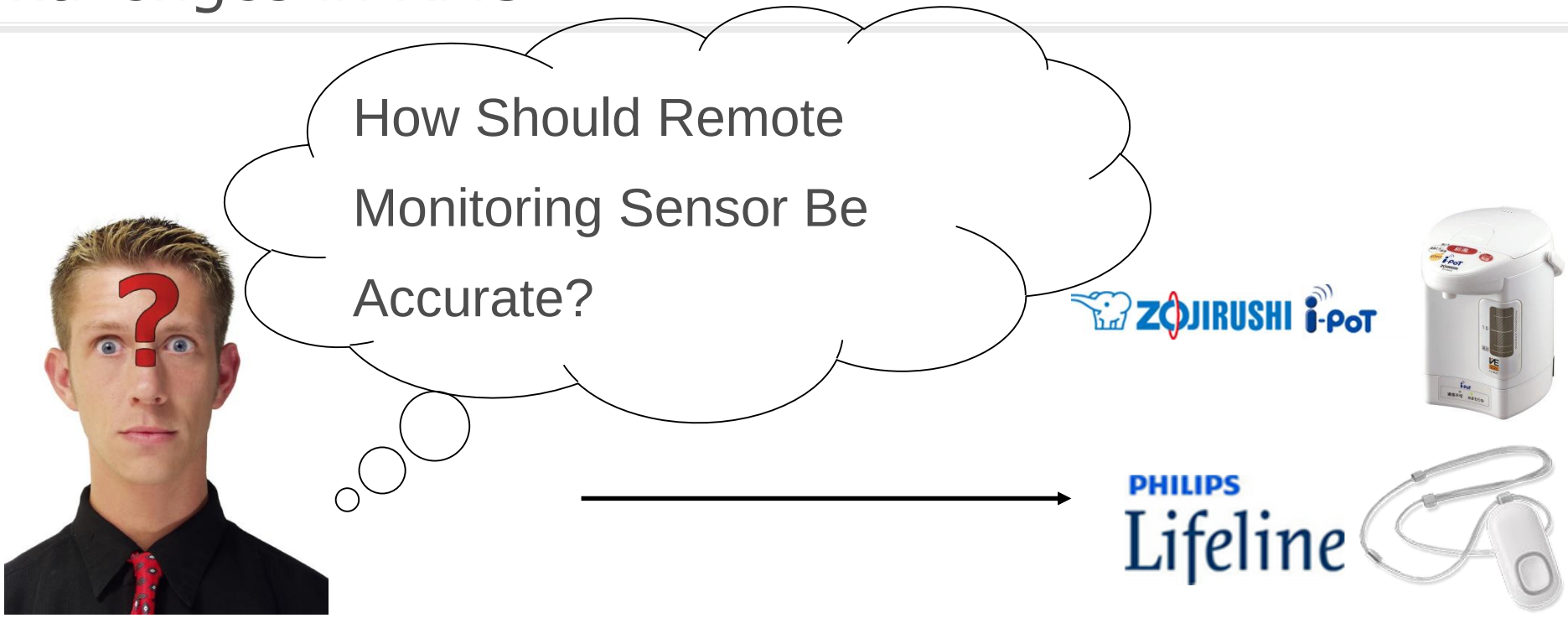
- **Monitoring by Networked Kettle (Zojirushi Corp.)**
  - An internet-connected kettle sends a signal when the elderly makes boiled water

ZOJIRUSHI i-PoT

- **Medical Alert System (Phillips)**
  - A pendant-style sensor detects elderly fall , and places a call for help

PHILIPS Lifeline

Challenges in RMS

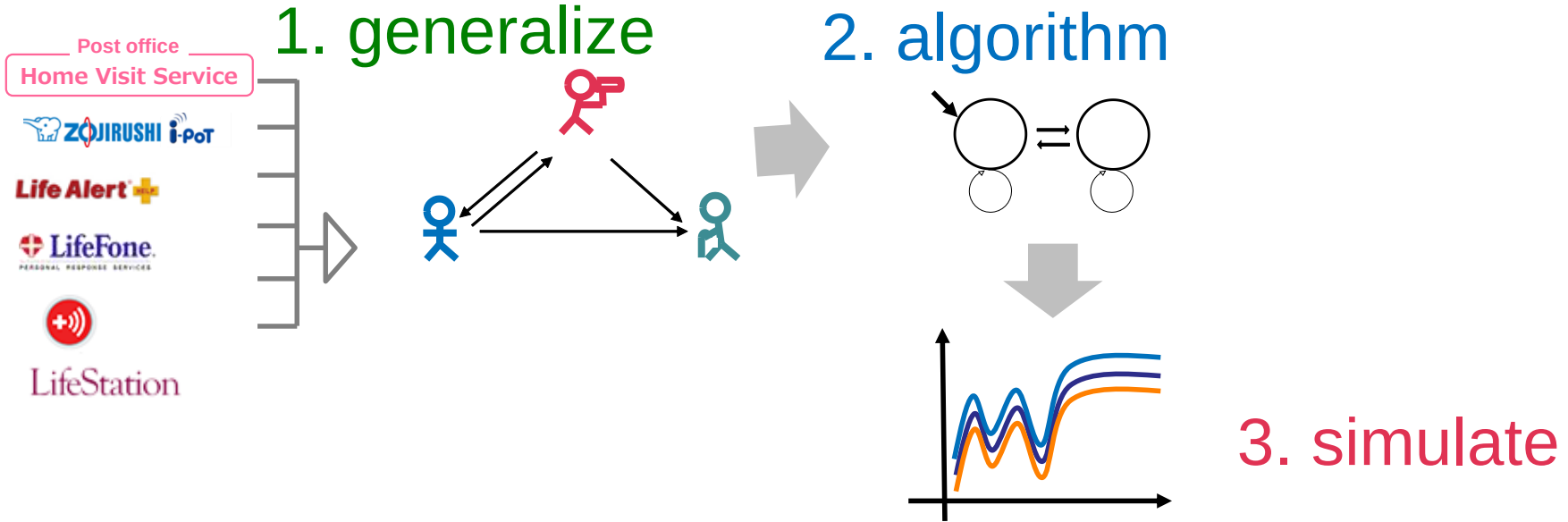


- Many companies and researchers have tried to improve the sensor accuracy in RMS
  - No one found the answer how should sensor be accurate

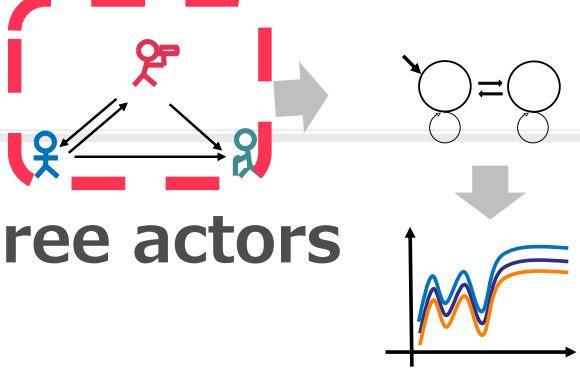
- To find the answer will provide many merits for providers
  - Decision making to develop a new RMS

Goal And Approach

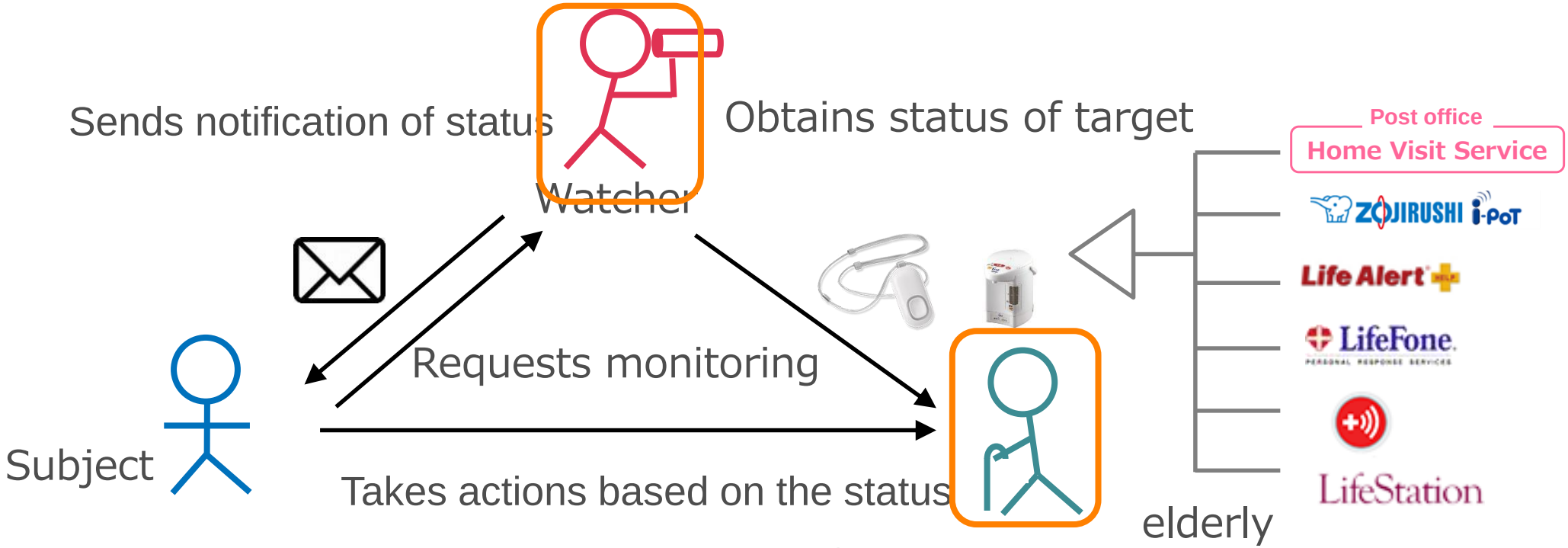
- Goal
  - To find the answer “How should RMS sensor be accurate?”
- Approach
  1. Propose a generalized model for RMS
     ->Find the key actors in RMS
  2. Think of actor’s algorithm
     ->Implements the actor’s function
  3. Conduct simulations using the actor’s algorithm



1.Three-Actor Model for RMS

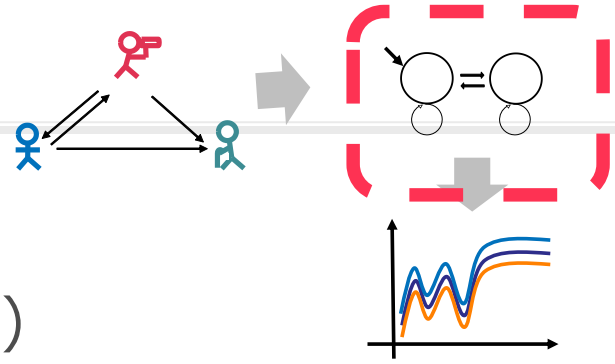


- Generalize RMS by interactions among **three actors**
  - **Elderly**: to be monitored by RMS
  - **Subject**: a user of RMS who indirectly monitors target
  - **Watcher**: a human or system checking status of target

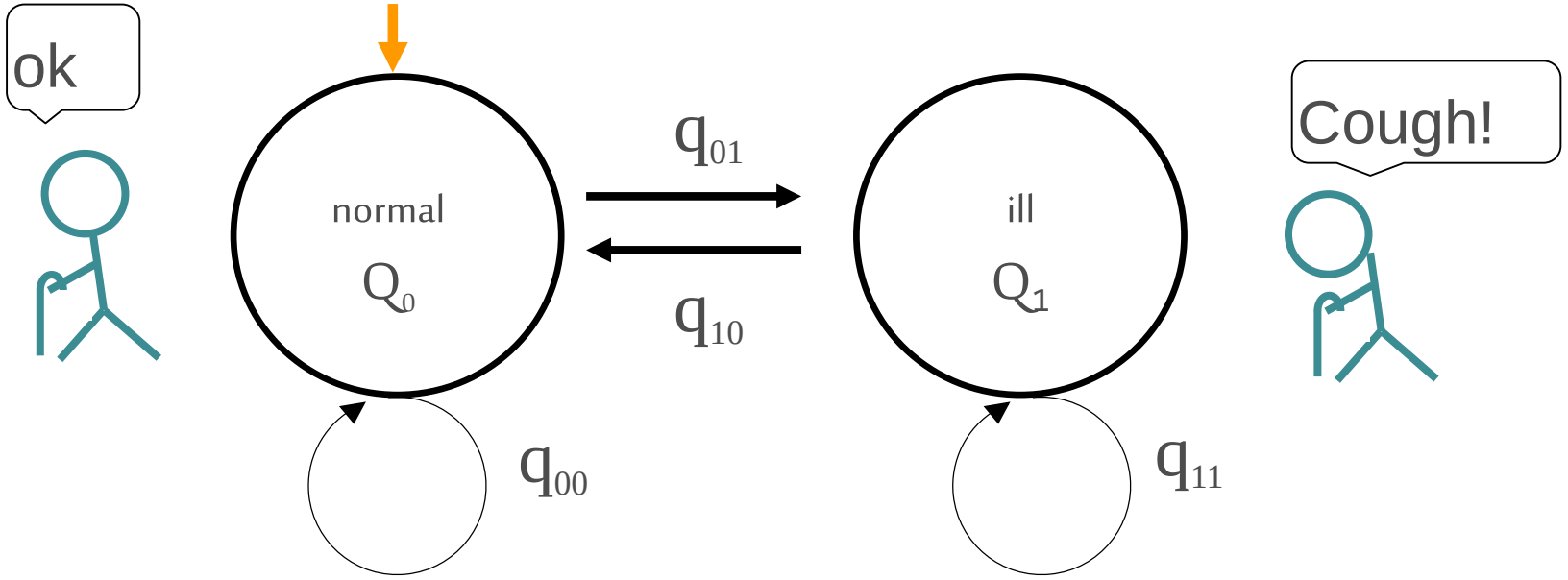


- Focus and think the algorithm for target and watcher
  - The RMS accuracy has strong relation with them

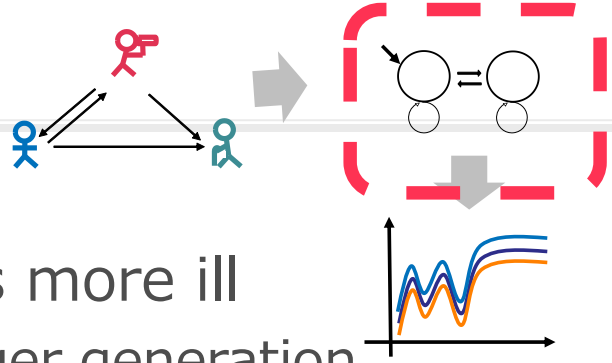
2.Two-state Model of Elderly



- Represents health status of elderly
  - Q_i represents elderly status (normal / ill)
- q_{ii} is probability of transition
  - Q_0 moves to the Q_1 with probability q_{01}
  - Q_o stays with probability q_{00}
  - q_{ii} is based on aging algorithm



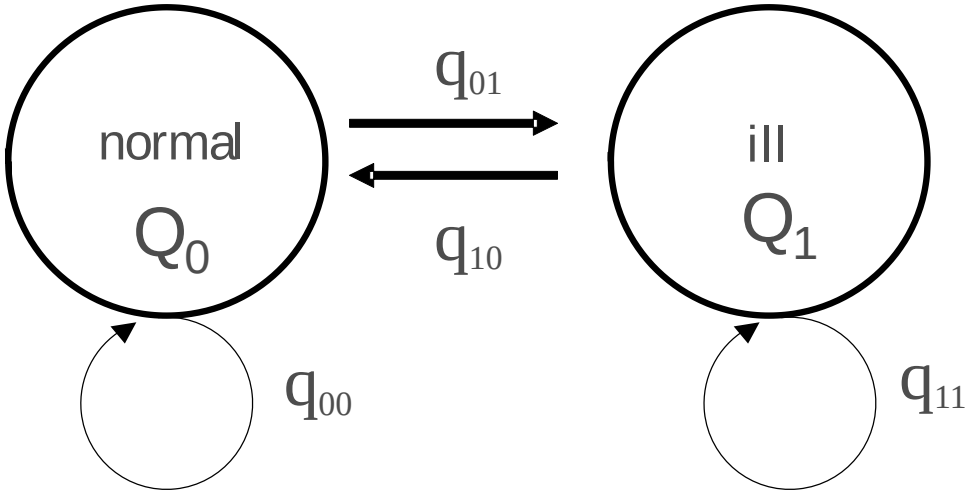
2.Aging algorithm

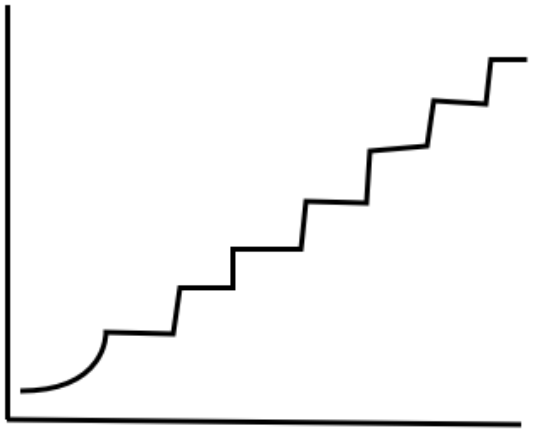


- Works as the aging for elderly model
  - If the model has aged, the model becomes more ill
    - Elderly tends to become more ill than younger generation

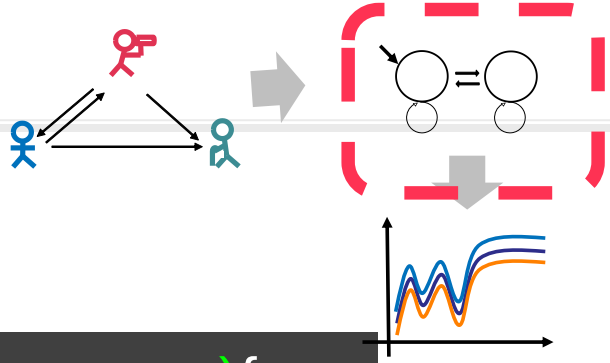
$$q_{01} = b * f(t)$$

  - b is transition probability
    - b becomes larger then q_{01} also becomes larger too
      →The models become more ill
  - $f(t)$ is step function that periodic increases in aging





2.Watcher's algorithm



- Define how to watch the elderly with simple interface monitor()

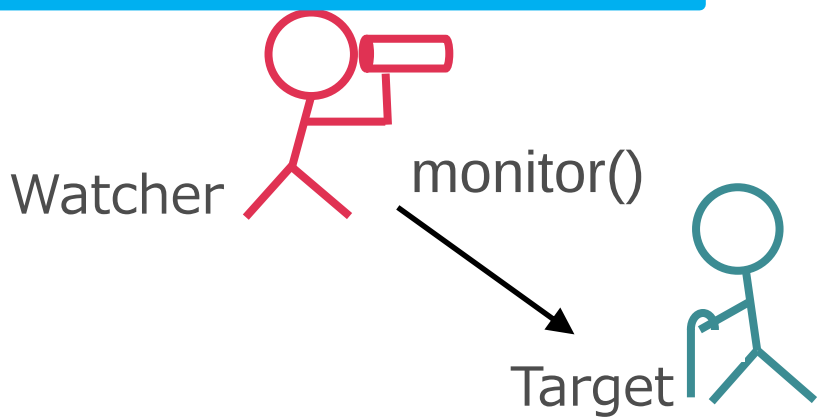
If the condition include the day, then watcher watch the elderly status

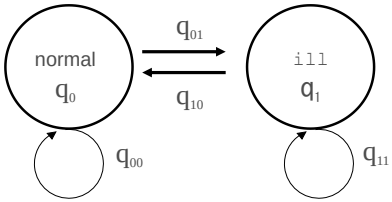
E.g. condition is "every Monday, Wednesday"

AND the day is "Wednesday"

The condition becomes true

```
monitor(day, condition, accuracy){
    if condition(day)  equal true
        return estimateState(accuracy)
}
```





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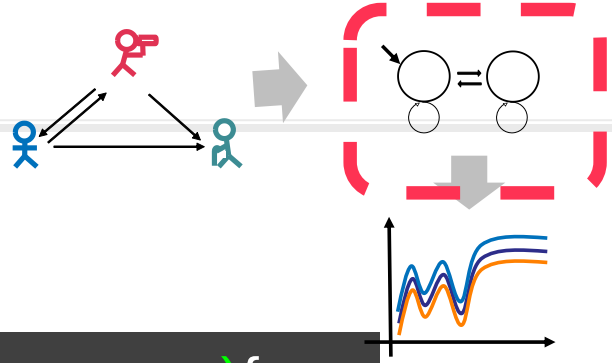

- Define how to watch the elderly with simple interface monitor()

```
monitor(day, condition, accuracy){
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```
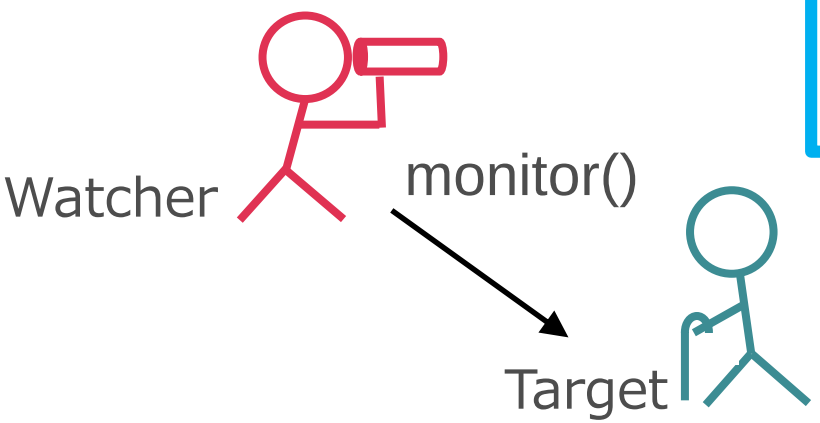
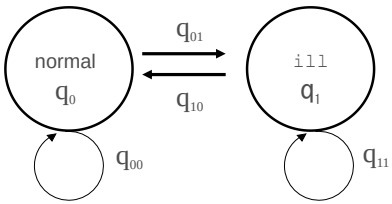
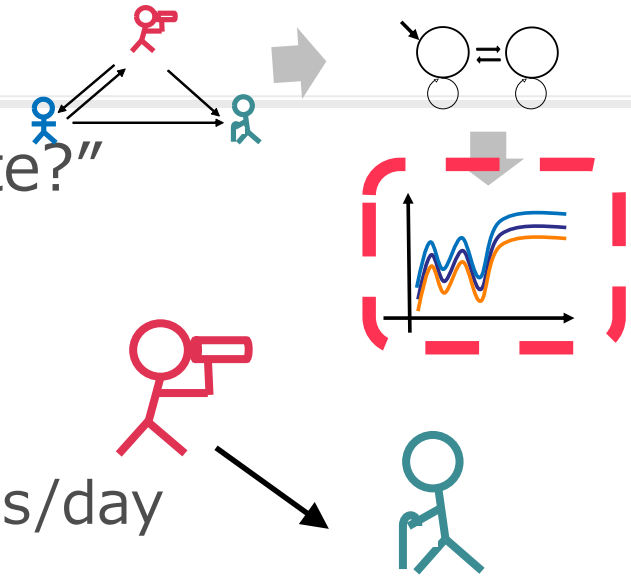

Estimate the elderly status with given sensor accuracy

E.g. if accuracy equal 0.8 then watcher monitors status with 80% accuracy





3.Simulation



- Aims to find “How should RMS be accurate?”
  - Simulating some types of elderly model with changing the sensor accuracy
- Settings
  - Watcher monitors the elderly status 1times/day
  - Simulation step: 1day
    - Total number of simulation steps are 4 years
  - Number of trials: 100 times
    - Using the average values as the result
  - Set 3 types of elderly models
    - Healthy, Normal, Sickly
- Task1: Validate the elderly model
- Task2:Confirm How Should RMS sensor be accurate

Task1: Validate the Elderly Model

- Confirm the elderly model's aging function works well
  - How many times does model become ill?

– Set 3 types elderly models

$$q_{01} = b * f(t)$$

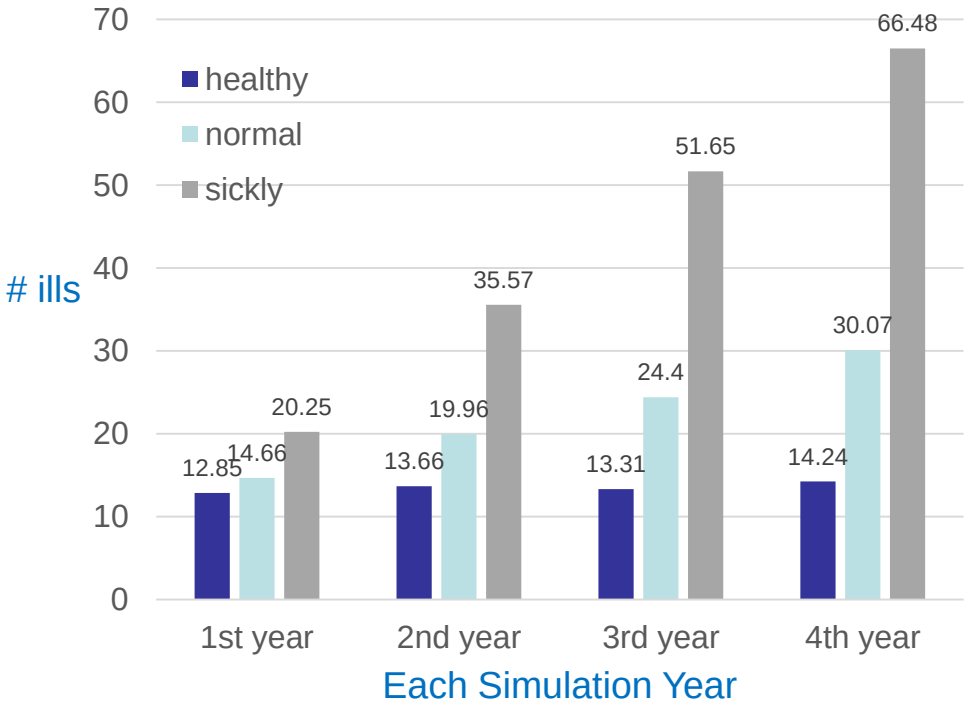
- $b_{healthy}$:0.0001
- b_{normal}:0.0010
- b_{sickly}: 0.0030

- Expected Result
  – Define frequencies of ills #ills

(#ills) Healthy < (#ills)Normal < (#ills)Sickly

  – Models would become more ill as time goes on

- Result



- Confirm the relationships

(#ills) Healthy < (#ills)Normal < (#ills)Sickly

Task1: Validate the Elderly Model

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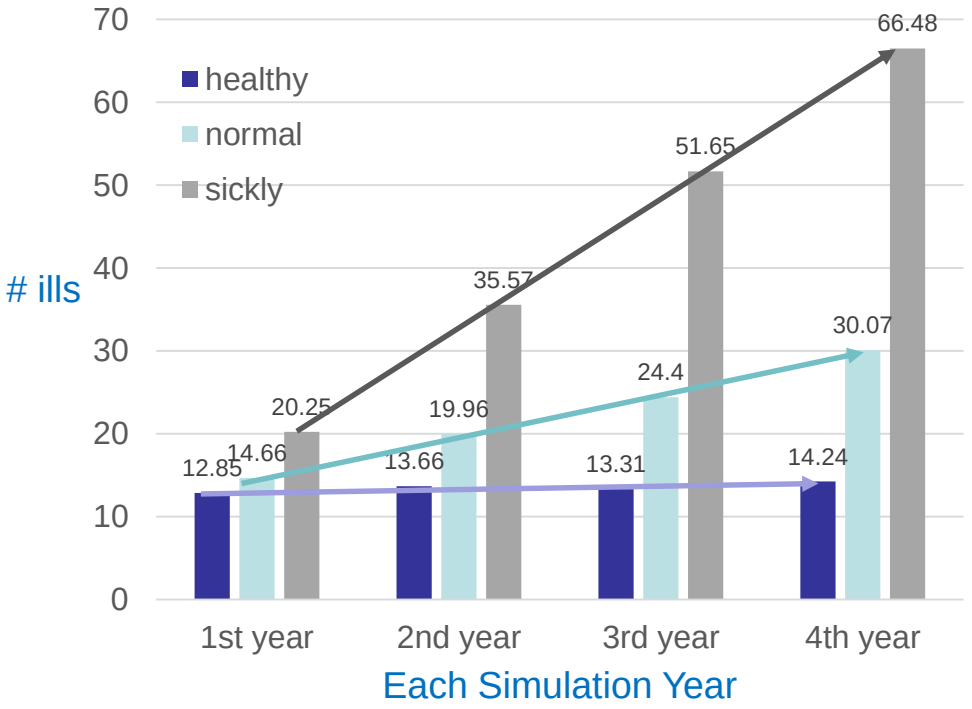

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(#ills) Healthy < (#ills)Normal < (#ills)Sickly

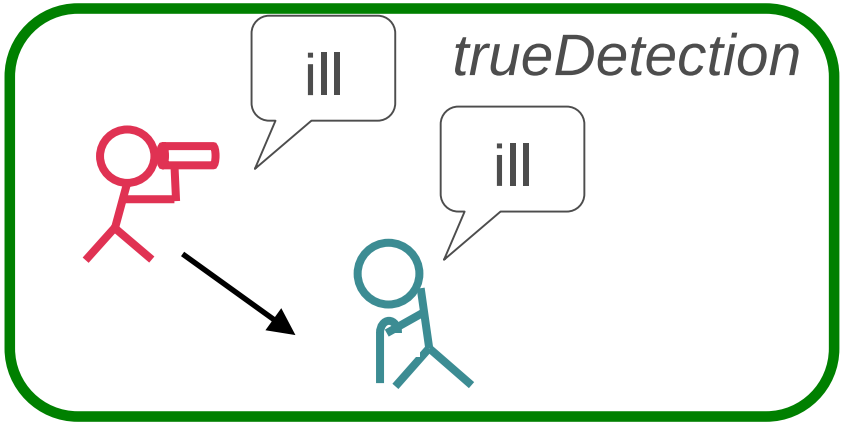
- Models become more ill as time goes on

Task2: Confirm How Should RMS sensor be accurate

- Confirm relationships between sensor accuracy and accuracy of RMS(dP)
  - Set sensor accuracies from 0.9000 to 0.9999

$$dP = \frac{trueDetection}{trueDetection + falseDetection}$$

trueDetection: Frequencies that watcher monitors the elderly correctly.



- Result
- Result shows

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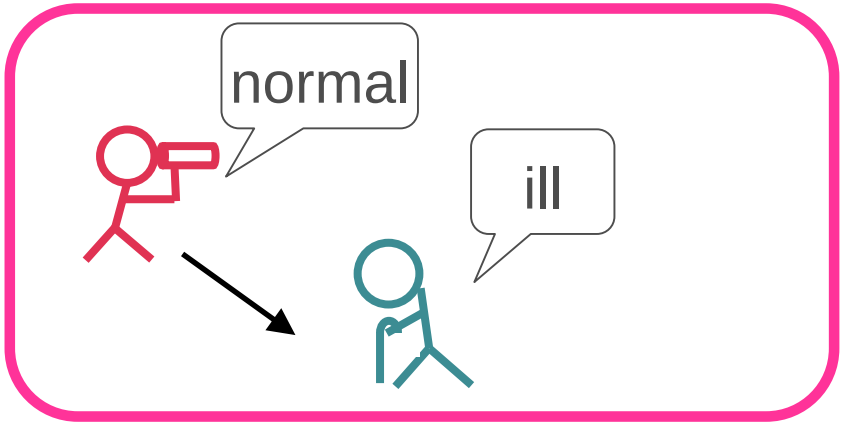
falseDetection: Frequencies that watcher monitors the elderly incorrectly.



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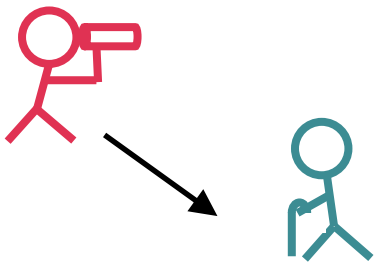

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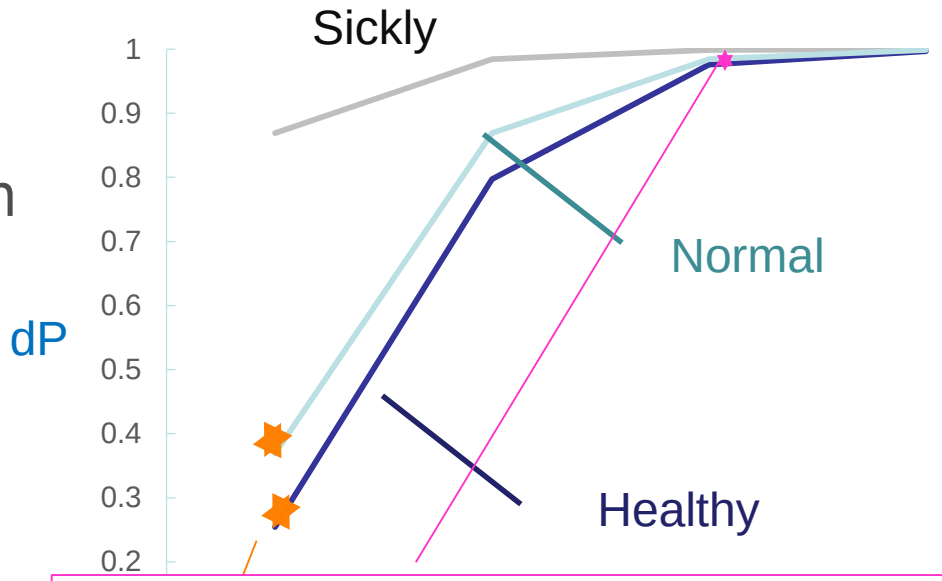


Little difference among all models and dPs are high

Both healthy and normal model, dPs are low

- Result shows

->If set sensor accuracy 0.999, RMS provides high accuracy service

Discussion

- Although set the accuracy as 0.9, the accuracy of RMS(dP)s become low
  - May difficult to provide the high accuracy RMS with only improving the sensor
  - Need to combine other resource based on the situation
    - caregivers
- Is the sensor accuracy 0.999 too high?
  - Need to compare the realistic sensor accuracy

- Simulation including business aspect, provides more interesting question
  - What is the reasonable cost for the consumers?

- Limitation
  - Our proposed models are too simple
    - To fix for realistic and variety

Conclusion

- In this paper we have found an answer “How should remote monitoring sensor be accurate?”
- Approaches:
  - Propose the generalized model for RMS
  - Design of key-actor’s algorithm
  - Conduct two simulations
- Result
  - If the accuracy of sensor > 0.9990 then the monitoring can detect elderly status with high accuracy

- Future work :)
  - Extend the models
    - variety, reality
  - Consider business aspects in the simulation

Why Some Model of Dp's Are Low?

- The elderly state data is imbalance data
- Evaluate the score how the sensor detect ill correctly.
  - Example of simulation
  -

Days(step)	1day	2day	3day	4day	5day	・・・
elderly status	normal	ill	normal	ill	normal	・・・
estimate status	normal	ill	normal	normal	normal	・・・

  - Result: dP = 1/(1+1) = 0.5
  - The one false detection drop dP's score
    - healthy and normal models become ill less than that of sickly
      - So the dP's score tend to drop by the one false detection

Why the differences has occurred?

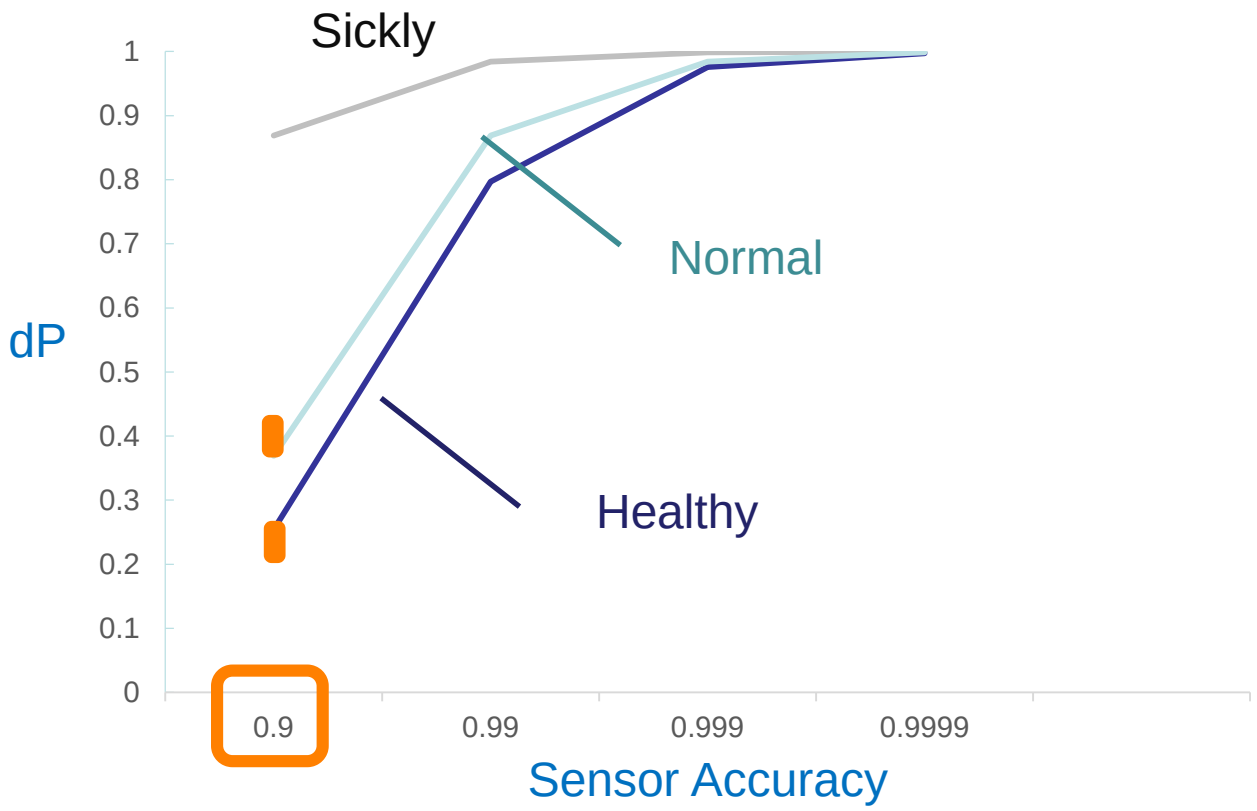
- Because the data が偏っている
- 私達はillの中の的中率を今回計算した

elderly status	normal	il	normal	il	normal	・・・
estimate status	normal	ill	normal	normal	normal	・・・

  - 結果: dP = 1/(1+1) = 0.5
  - 一回の失敗がかなりdPの精度を下げる
    - 今回のようにhealthy model, normal modelは病気になることが少ないため今回のようにセンサ精度が0.9だと低い結果になると

Discussion

- Although set the accuracy as 0.9, the accuracy of RMS(dP)s become low
  - Difficult to the high dP's



Discussion

- Although set the accuracy as 0.9, the accuracy of RMS(dP)s become low
  - Difficult to provide the high accuracy RMS with only improving the sensor
  - Improving accuracy, need to combine other resource (caregivers …)

- Simulation including business aspect, provides more interesting question
  - What is the reasonable cost for the consumers?
  - How accuracy do consumers need?