

Abstract

People over age 65 are expected to cover 20% of the population in 2030. Aging of the baby boomers has become an important social issue.

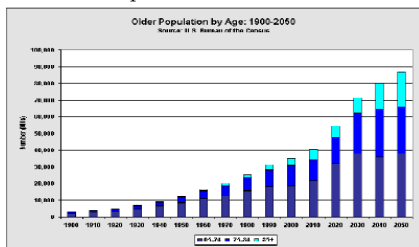


Table 1 : compiled by the U.S. Administration on Aging based on data from the U.S. Census Bureau.

It is envisioned that the sensor network technology:

- can be used to collect useful behavioral and biological information to monitor the wellness of an elderly person
- allows the elder to live independently and economically
- help decrease the annual expenditures on health care

Benefits of sensor networks:

- low cost (installation and maintenance)
- non-invasive monitoring scheme

The goal of this project was to build a statistical behavior model of an elderly person living alone with the PIR (passive infrared) sensors. Then use the model to cluster the collected data and detect if any irregularity in behavior.

Behavior Learning

K-means algorithm :

1. Split data points into random clusters
2. Compute the mean of each cluster
3. Find new clusters based on means computed in step 2
4. Go to 2 until no change in cluster membership
5. Compute the covariance of each cluster

EM (expectation maximization) algorithm :

→ Model: mixture of Gaussians

→ EM finds the maximum likelihood estimates (means and covariance) of the parameters



Abnormal Behavior Detection

1. Compute the formula for each data point (X_i)

$$(X_i - \mu^k)^T \sum_{k=1}^{k-1} (X_i - \mu^k)$$

2. If the value is greater than a threshold for all of the clusters than point is abnormal (we set threshold = 4 because it includes all the normal patterns)

Experiments

- **Hardware** -- Trio notes (radio: TelosB) with passive infrared (PIR) sensor (Figure 1)
- **Software** -- threshold for PIR sensors - TinyOs
 - sampling timer - TinyOs
 - readable format, sensor data to a text file - Java
 - computed trajectories of the data reading - Matlab
- **Testbed** - miniature model house (Figure 2) -- 5 rooms, bedroom, bathroom, living room, dining room and kitchen with one Trio mote in each room
- **Trajectories** -- Each experiment: 6 minutes in experimental time = 60 minutes in real time
 - constructed 3 basic patterns that elders travel 6 - 7 am and generated 10 experiments from each pattern
 - used 3 out of the 30 experiments for testing (Figure 4)
 - constructed 7 abnormal behaviors, such as not waking up, not going to the bathroom or kitchen, wandering through house, continually going to the bathroom or even staying in the bathroom for a long period of time. (Most likely place of falls) (Figure 4)



Figure 1- Trio mote



Figure 2- Miniature model house

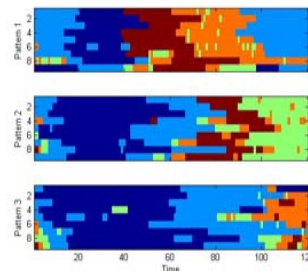


Figure 3: Location of the sensor with the highest number of detections recorded in every 3 sec. block

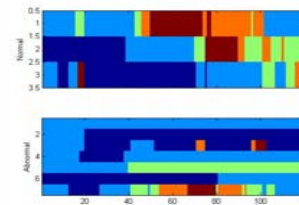


Figure 4- Normal, Abnormal patterns

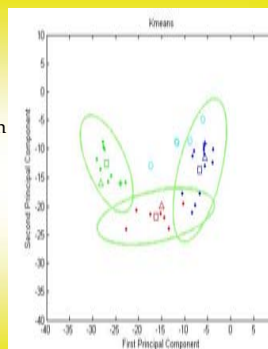
Results

→ Applied PCA (principal component analysis) to reduce the dimension of data from 120 to 4

K-means

K-means results (Legend)

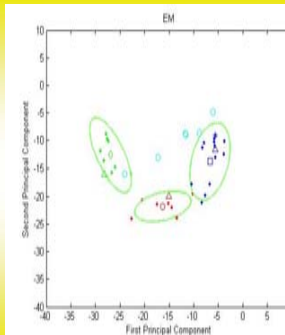
- Dots -- data points in different colors
- Squares -- mean (center) of each cluster
- Cyan circles -- abnormal behaviors
- Stars -- points that were constructed as abnormal behaviors but are classified as normal behavior
- Triangles -- testing points for each pattern



EM

EM results

EM legend is same as K-means legend, above



Conclusion

For my research we concluded that clustering of data was a good way to model data points. Also, the EM algorithm was more accurate for my research because it identified more abnormal behaviors than the K-means algorithm.

Future Work

- A realistic testbed instead of a miniature model to obtain precise, real and large amounts of data
- Incorporate additional sensor data, e.g. image sensor data
- Safety monitoring: cameras, bio-monitors and falling sensors
- Assistance: daily routine reminders to the user