

# A Pervasive Body Sensor Network for Post-op Monitoring

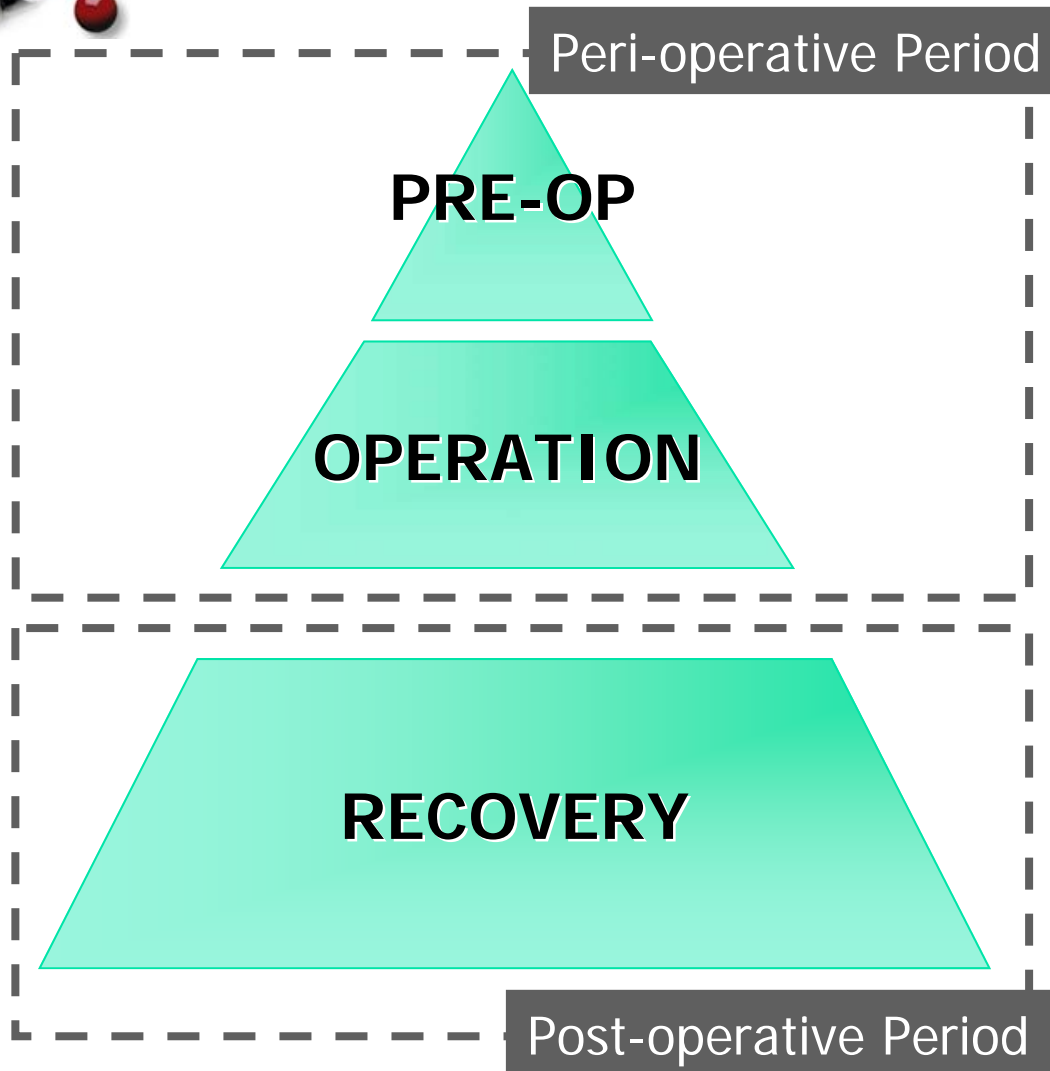
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# Setting the Scene

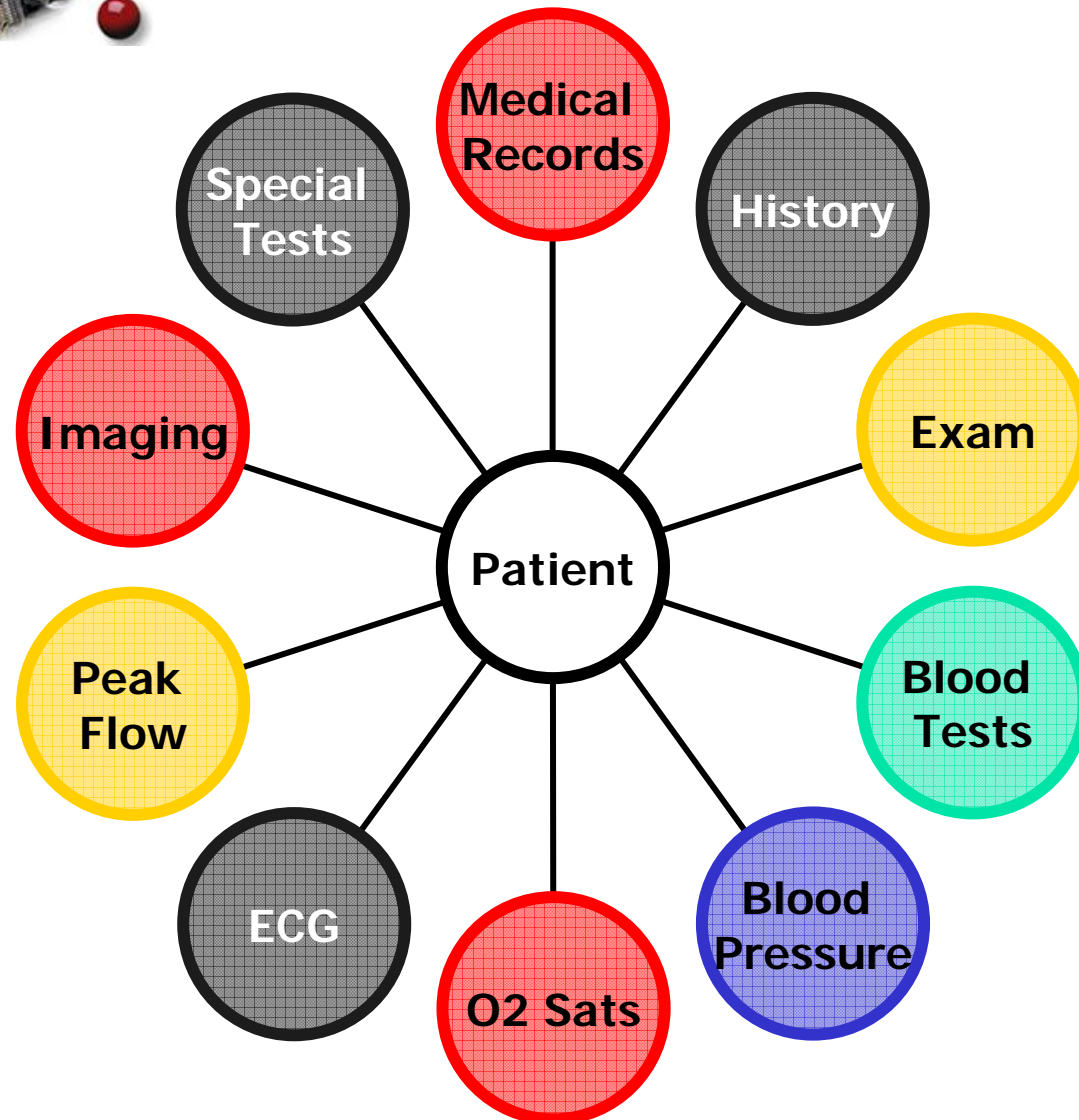
- **The role of BSN in post-op monitoring**
  - 40.3 million inpatient, 31.5 million outpatient operations per annum  
(US National Center for Health Statistics)
- **The reason for monitoring in the post-op period**
  - Immediate/Early/Late complications
- **Developing a pervasive monitoring system**
  - Detect activity, recovery, & physiology
  - Detect complications early

# Monitoring Requirements



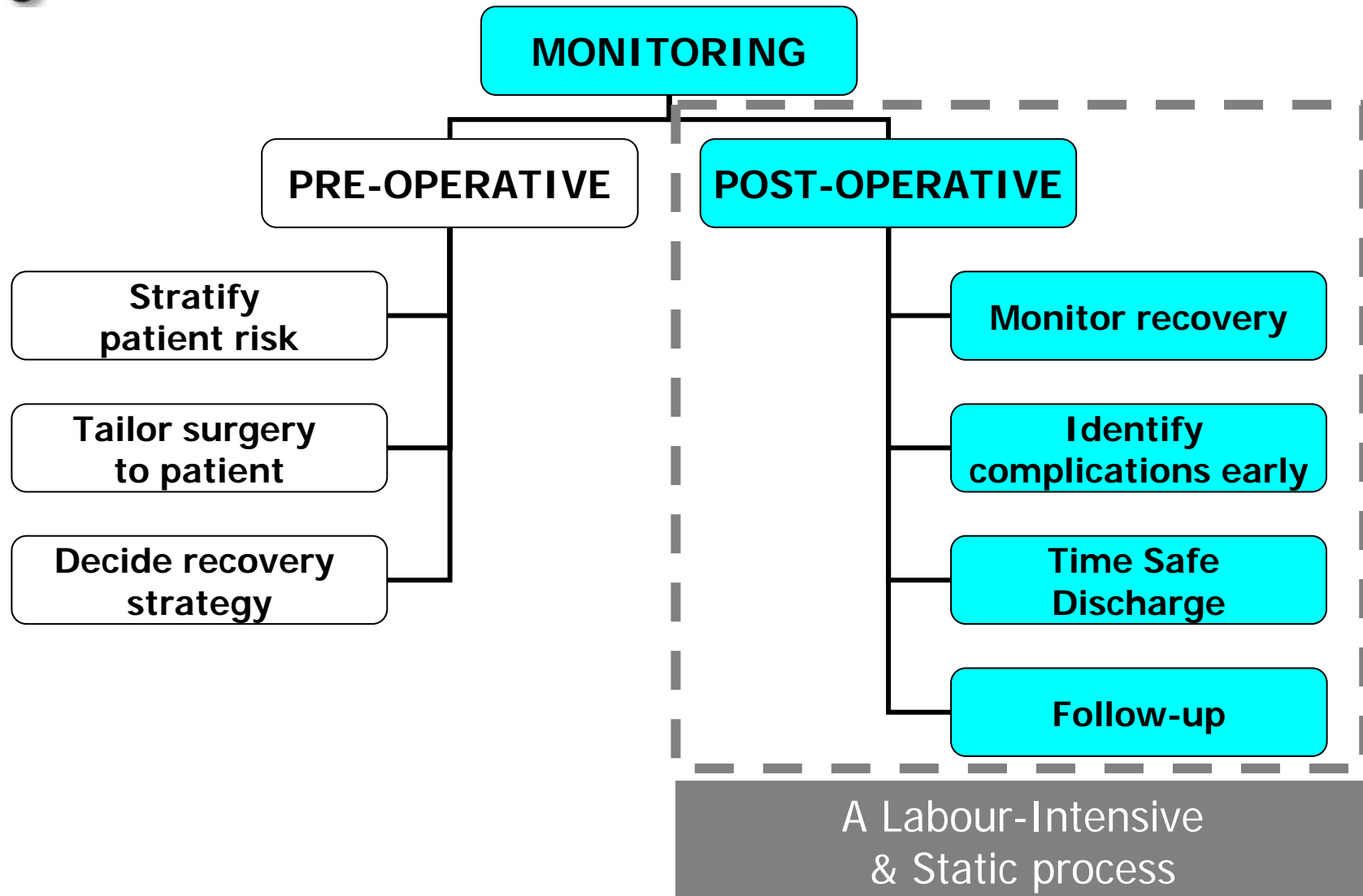
- Current monitoring is most intensive here
- Traditional monitoring difficult here
- Longest period of time surrounding the operation
- Patient at home

# Current Monitoring Tools



Only a SNAPSHOT of a patient's health

# The Goals of Monitoring





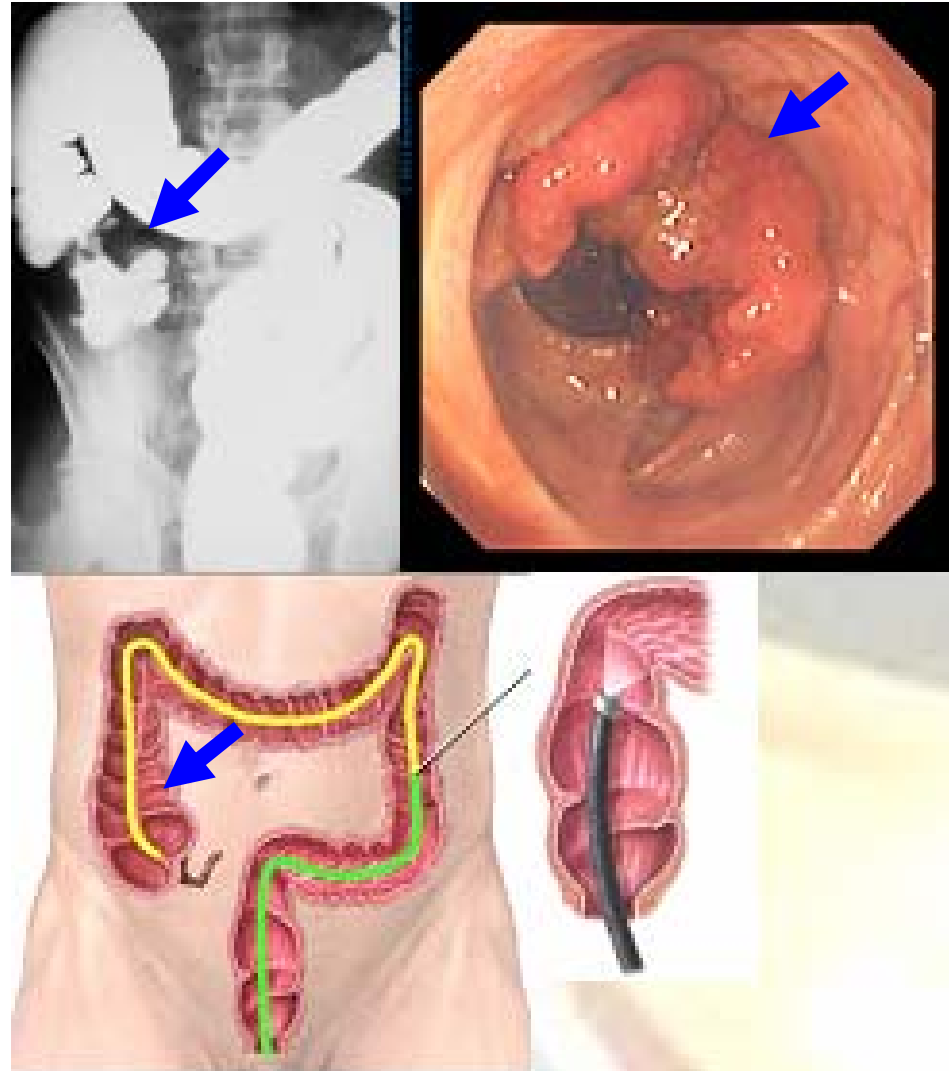
# How Can We Prevent Complications?

- **Identify patient factors**
  - Age
  - Co-morbidity (diabetes, COPD, smoking, obesity, steroids)
- **Identify operative factors**
  - Low/Med/High risk procedures
  - Surgeon-related factors
- **Precautions can be taken**
  - Minimise trauma (Laparoscopic surgery)
  - Goal-directed recovery
- **ULTIMATELY COMPLICATIONS STILL HAPPEN**

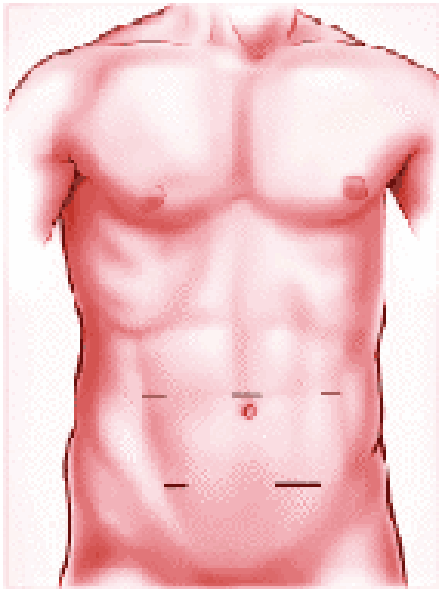
# The Consequence of a Complication

## Patient X

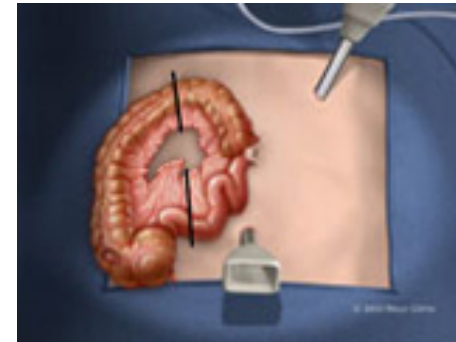
- Age 69
- Male
- Diagnosed with colorectal cancer
- Co-morbidity
  - Diabetes
  - Smoker
- Planned curative bowel resection



# The Consequence of a Complication



Laparoscopic (closed)



- Laparoscopic (Keyhole) resection of cancer
- Two segments of bowel anastomosed (joined)
- Keyhole Wounds Closed
- Sent home day 5

# The Consequence of a Complication

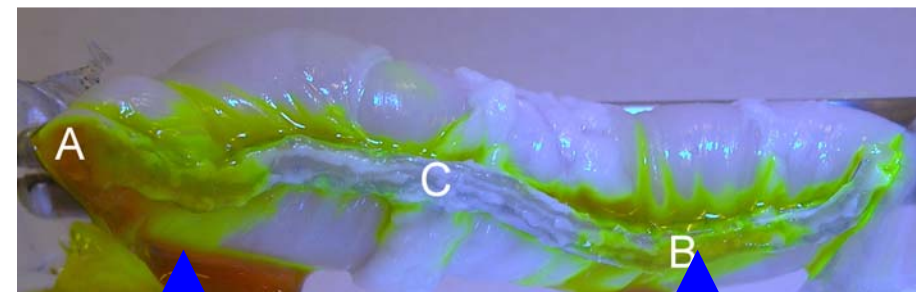
## ■ Day 7

- Tachycardic (HR 120)
- Temp 38 °C
- Resp Rate 24
- Abdominal tenderness



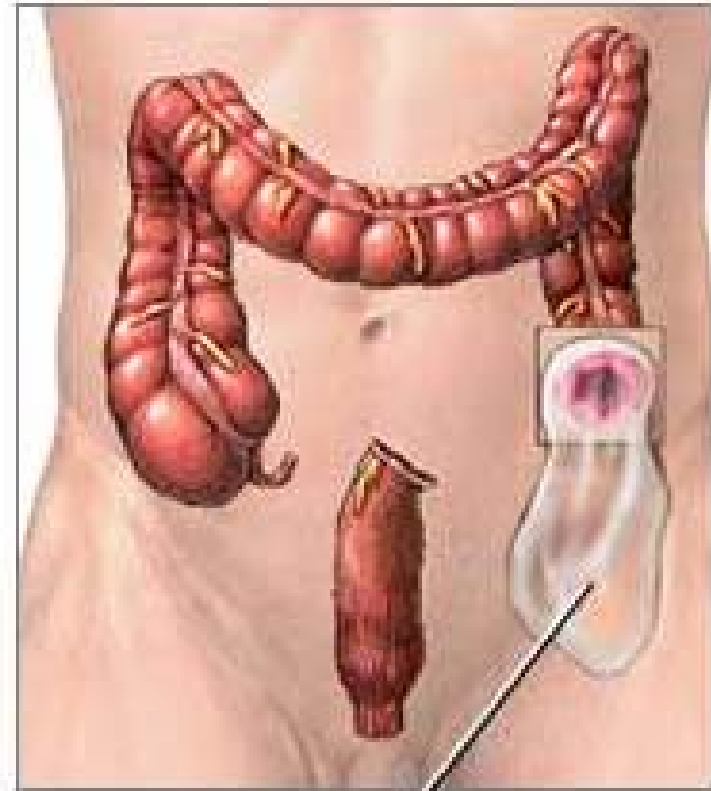
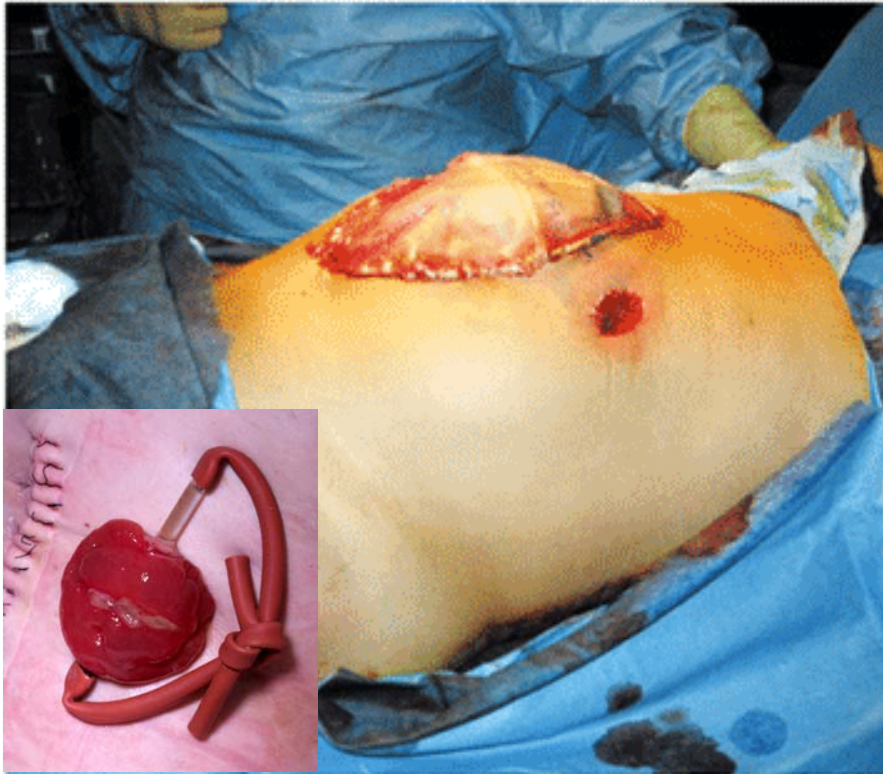
## ■ CT Scan

- Leak from anastomosis
- Emergency surgery
- 21-day ITU admission
- Stoma



Leak Sites

# The Consequence of a Complication



Colostomy bag



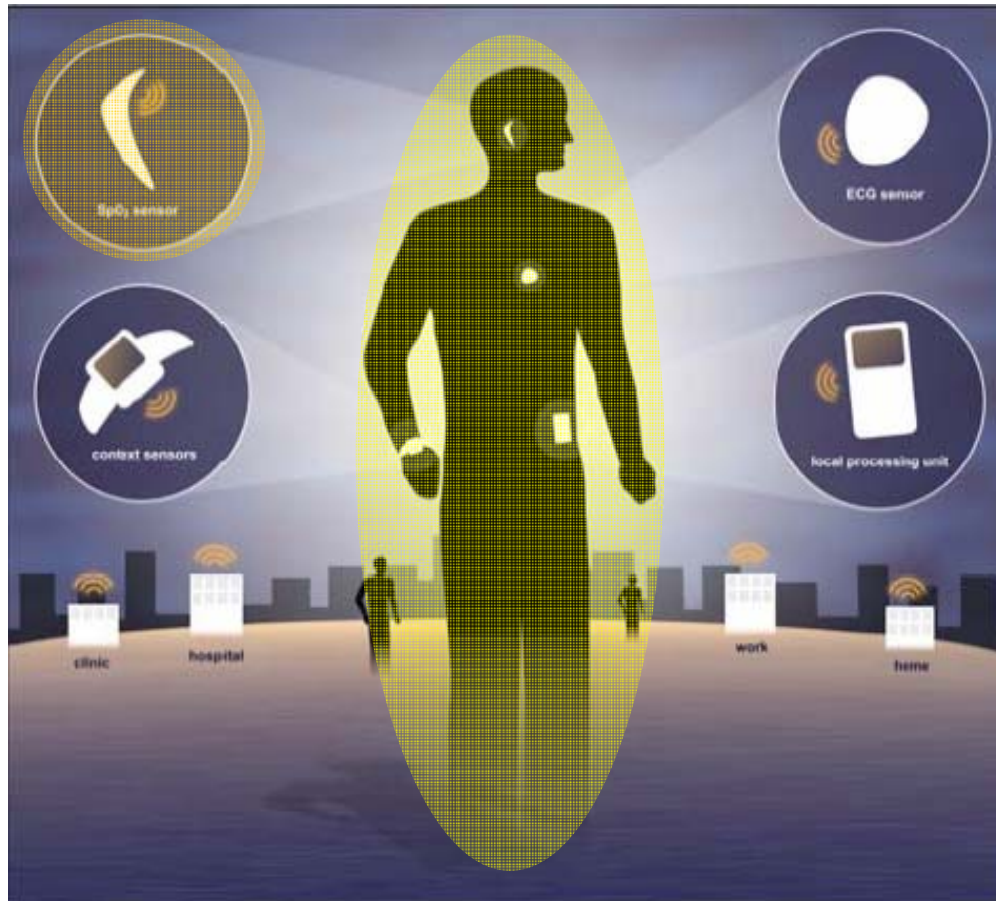
# How Can a Pervasive System Help Detect Complications Early?

- **Measure and quantify recovery**
  - Mobility (Impaired/Recovering/Normal)
- **Determine normal activities**
  - Walking, Sleeping, Reading, Eating & Drinking
- **Monitor body physiology**
  - Heart rate, Oxygen saturation, Temperature
- **Allow safe discharge**

# The Post-op Home Setting



# A BSN for Surgical Patients



## Pulse Oximetry

- O<sub>2</sub> % sat
- HR

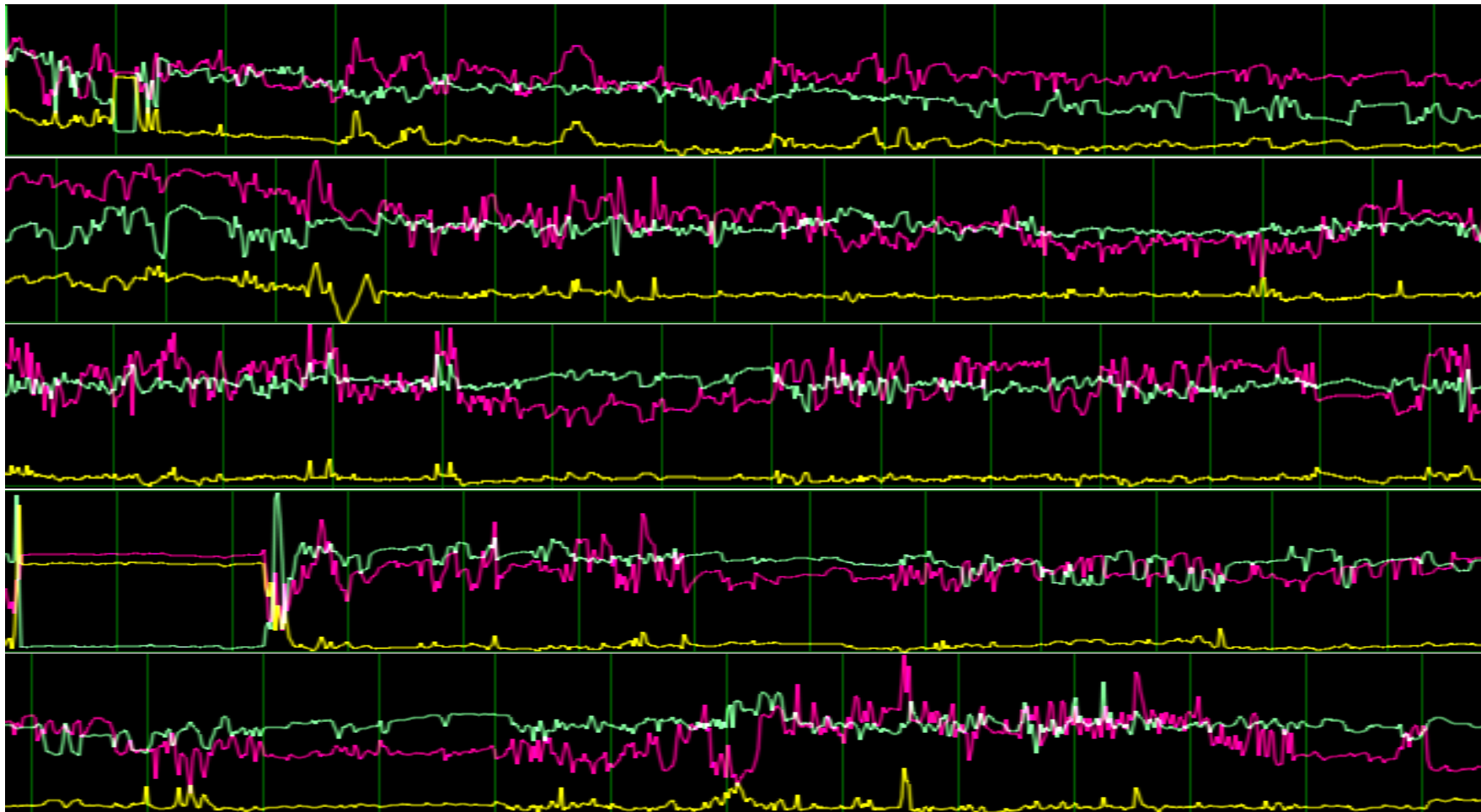
## 3 Accelerometers

- Activity type
- Mobility Impairment
- Recovery



# Motion Data: 5 hours of a Patient's day

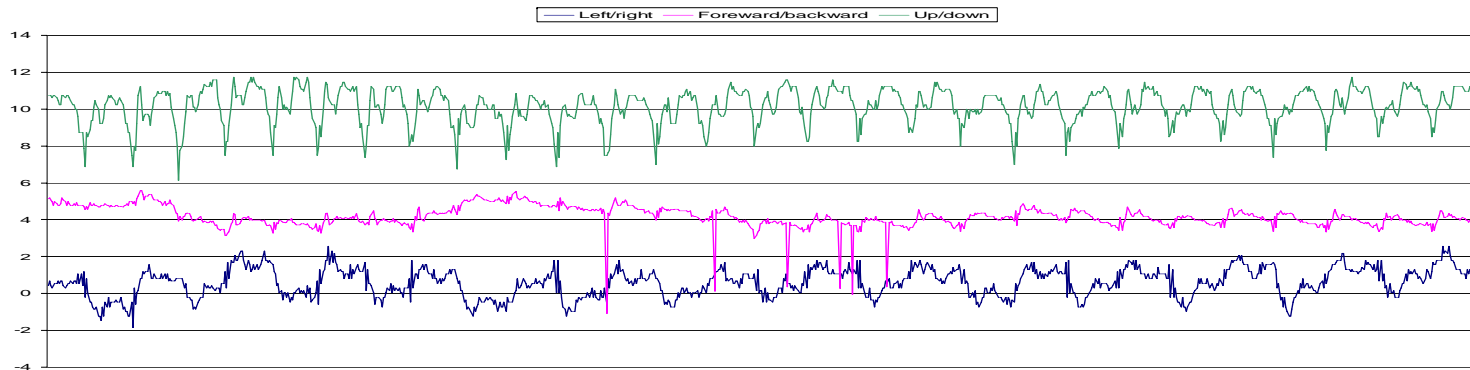
How can we identify mobility impairment, activity, & recovery?



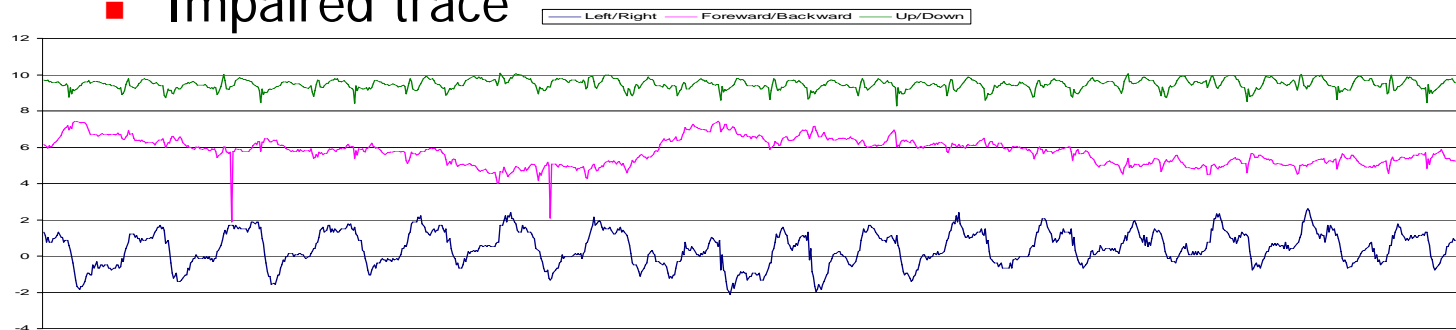
# Challenge 1: Mobility Impairment

- Looking at a subject's mobility before (normal) & after (impaired) injury

- Normal trace



- Impaired trace



- Visually a difference is seen. Can this be quantified?

```

    .001
    u80He1
    z80B01
    l...
    f...
    z8c^c^
    "8a"
    88H"
    n88=VH:
    |8888VH"
    "8888cH"vul
    F88888"
    zZUF88F1
    |88H n8U
    "8H" "8"
    "8w" 01
    c8a" 8"
    z8U" ul
    "80"
    n8"
    s1"
  
```

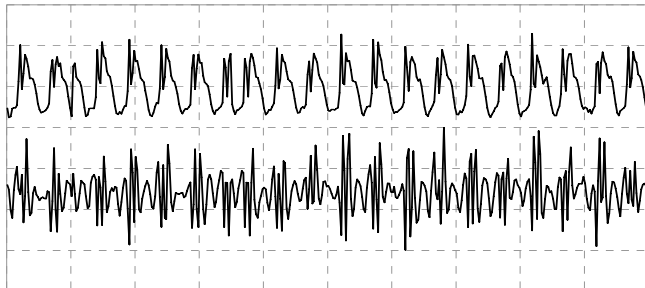


# Mobility Impairment Recognition Methods

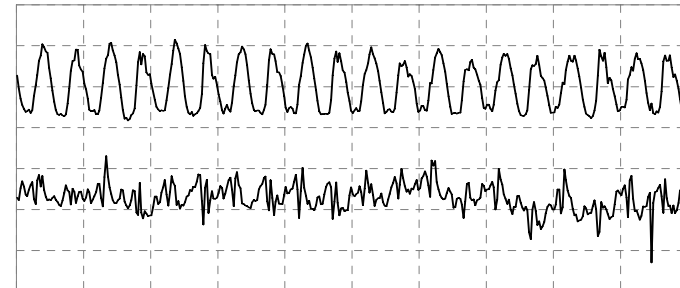
## ■ STEP 1: Source Separation

- ICA (independent Component Analysis), using Maximum Likelihood to recover source components.
- ICA is a generative model that describes how the observed data is generated by a process of mixing source components.
- Feature Extraction from the source components (rather than raw signals) is a good way of dealing with multi-sensor data with correlated information.

ICA components - normal subject



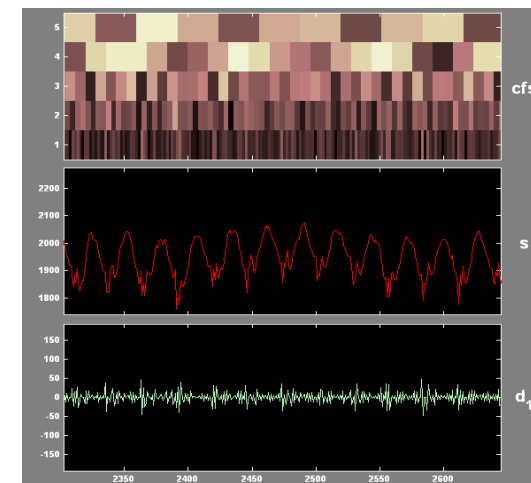
ICA components - impaired mobility





# Mobility Impairment Recognition Methods

- STEP 2: Multiscale Feature Extraction
  - Using Wavelet Transforms
  - Allows a multiscale representation of the signal in terms of a fast decaying oscillating waveform (mother wavelet), chosen to be Daubechies 4
  - Spatio-temporal feature extraction was achieved using a moving window across the wavelet transform and calculating the windowed wavelet transform energy.





# Mobility Impairment Recognition Methods

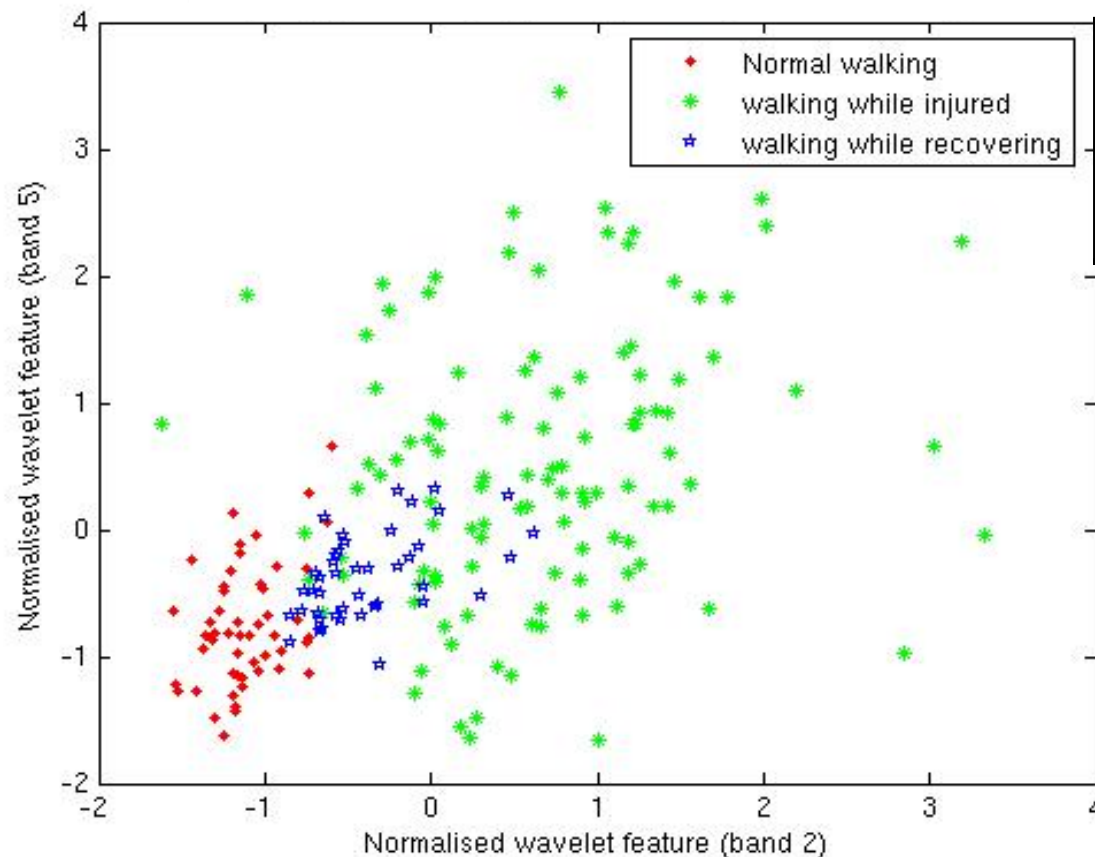
- **STEP 3: Margin based Feature selection**
  - Used to select features that provide optimal clustering between impaired and unimpaired activity.
  - This method can handle correlated features and provide the features that can be plotted or used in a classifier\*.
  
- **STEP 4: A KNN classifier**
  - Simple classifier that can deal with non linear class boundaries (choice of k is important though).
  - k-fold cross validation was used to observe rates of correct classification.

\* R. Gilad-Bachrachy, A. Navotz and N. Tishby, **Margin Based Feature Selection Theory and Algorithms**, Proc. 21<sup>st</sup> International Conference on Machine Learning (ICML)}, 2004.



# Mobility Impairment Recognition Results

- Data from the subject with an injury on treadmill
  - Results for different values of k (KNN) using 5 fold cross validation, and scatter plot



K=5	K=10	K=20	K=25
91.22	91.22	91.22	89.27

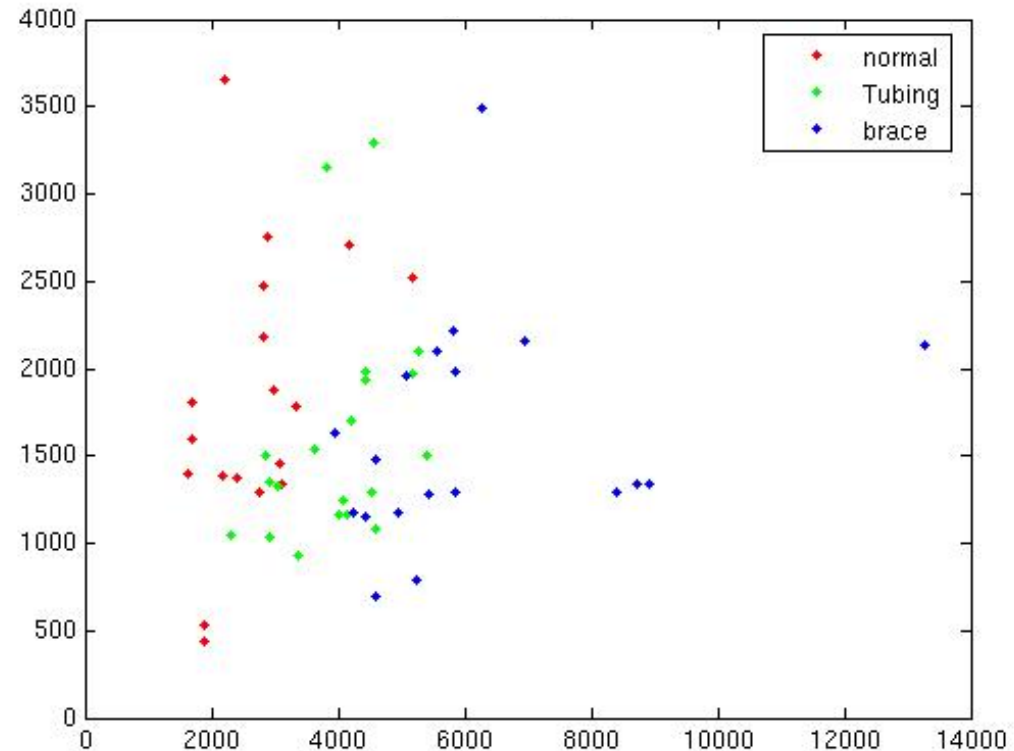
- Clustering seen into three distinct groups:

- Normal
- Recovering
- Impaired



# Mobility Impairment Recognition Results

- Simulating normal vs. impaired mobility (N=10 subjects)
  - Scatter plot for subject number 1
  - Table shows averaged results for 5-fold cross validation per subject. (K=5)
  - These results are for two classes.

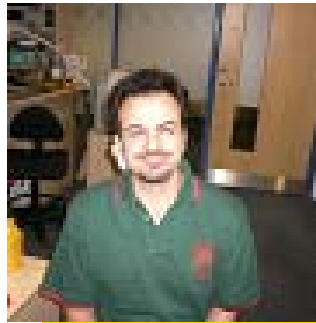


1	2	3	4	5	6	7	8	9	10
93	90	80	83	89	82	92	96	83	72

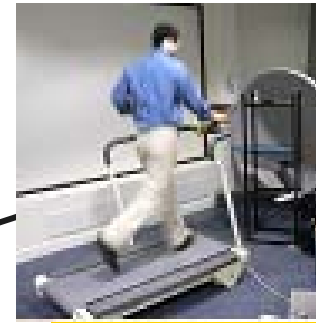
# Challenge 2: Monitoring Activity



- Sitting
- Reading
- Writing
- Coughing



- Eating
- Drinking



- Running

ACTIVITY

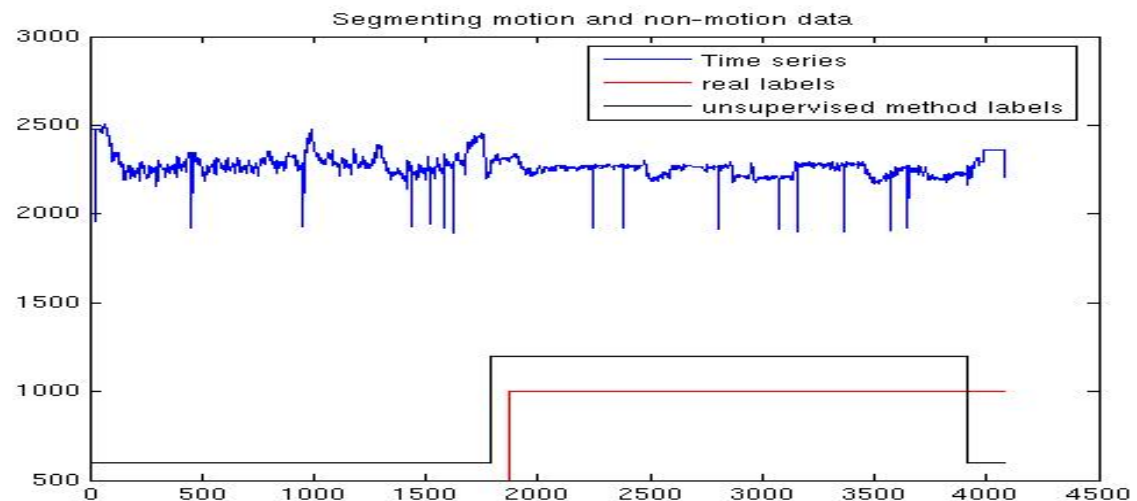
- Walking normal
- Walking impaired



- Lying down
- Sleeping

# Active vs. Inactive Movement

- Feature extraction/selection methods as described previously
- Unsupervised segmentation of activities into:
  - Active (walking, cooking, moving around)
  - Inactive (reading, sleeping)
- **Result:**

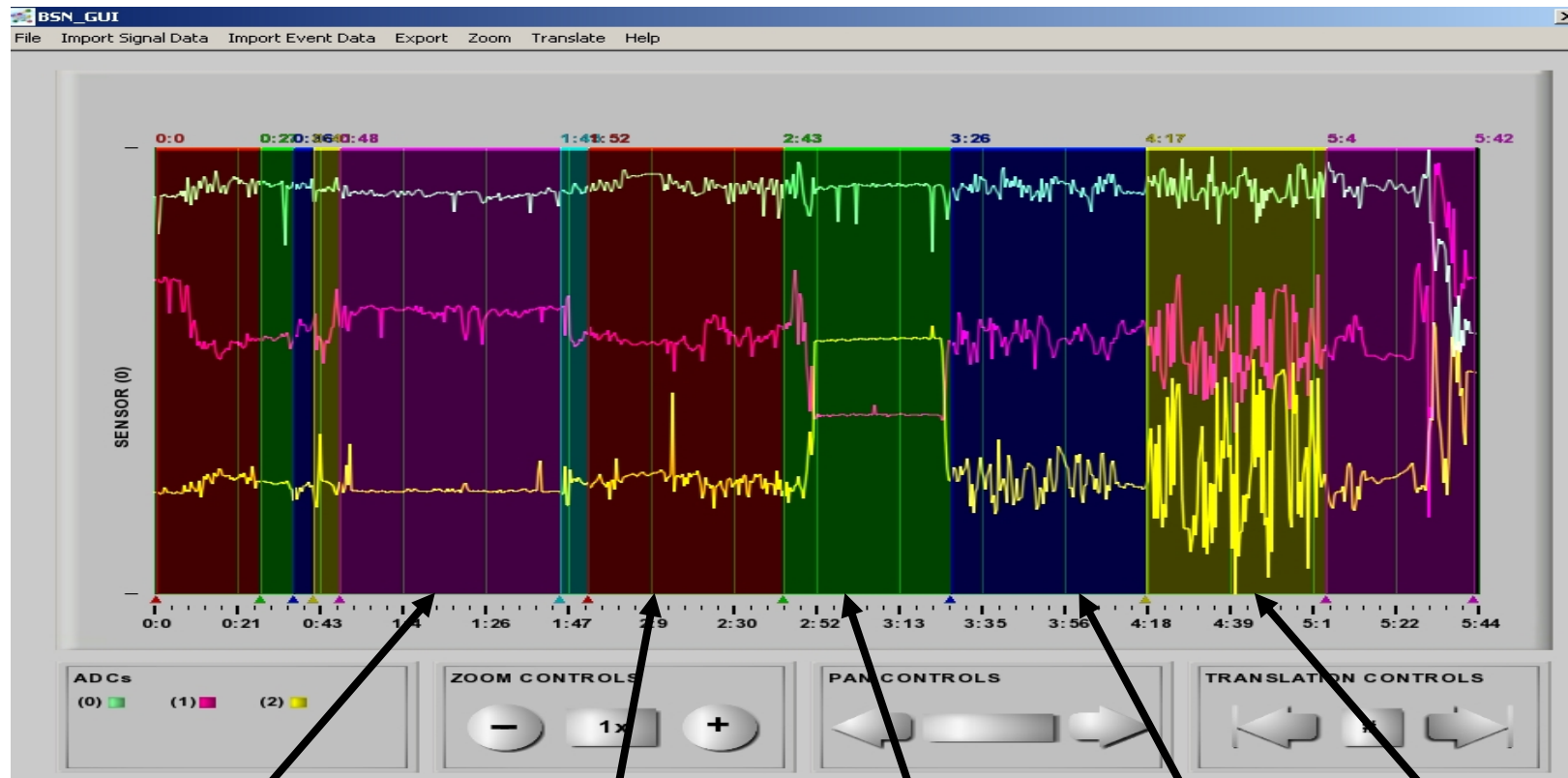


- Correct classification of **97%**
- By training on a very short period (about 3 minutes), and testing on 1 hour period, active for 68% of the time, inactive for the rest
- Determine duration of periods of activity/inactivity



# Activity Recognition

- **Lab-based study:**
  - 10 subjects, home environment.
  - Results for 1 subject:



Reading

Walking slowly

Lying down

Walking fast

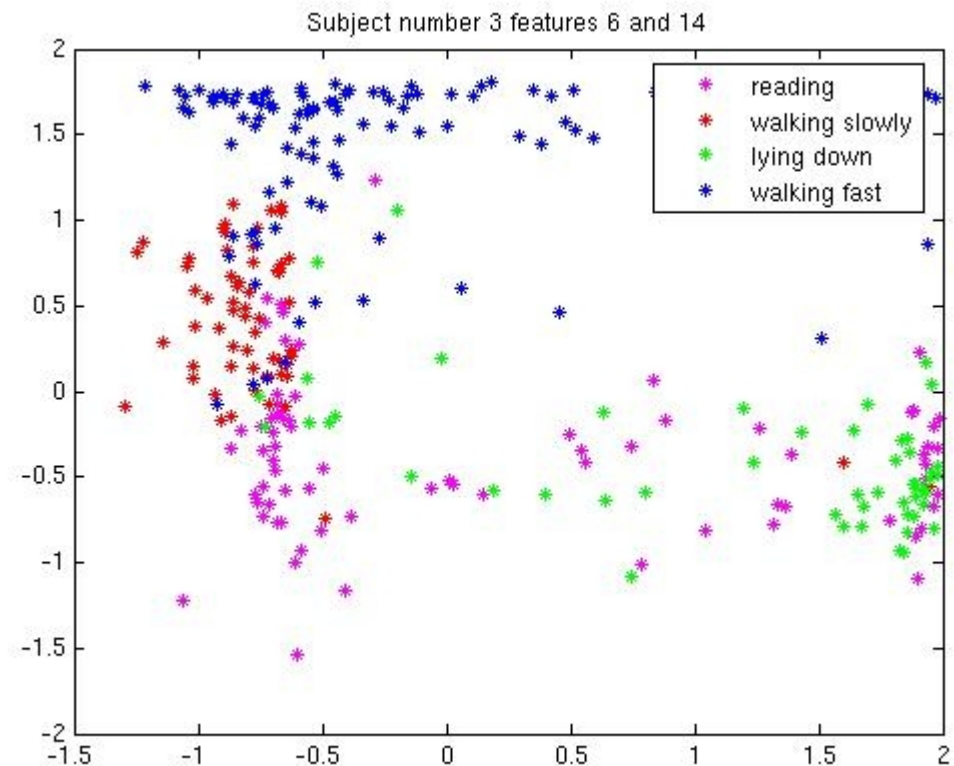
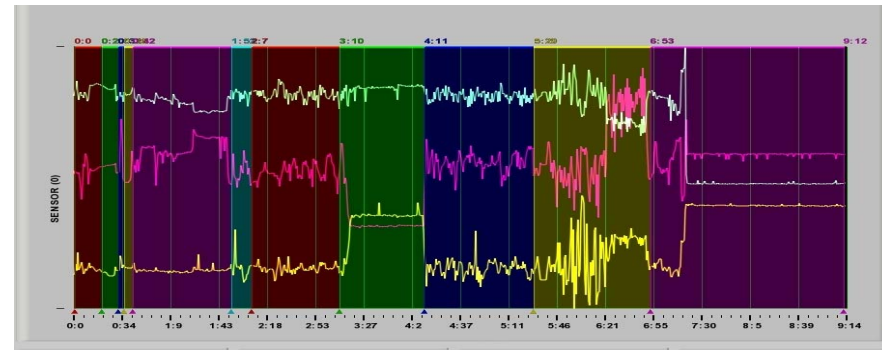
Running



# Activity Recognition

## Results:

- 4 activities
  - Reading
  - Walking slowly
  - Lying down
  - Walking fast
- Wavelet analysis & Margin Feature Selection
- For one subject
  - Clustering is seen

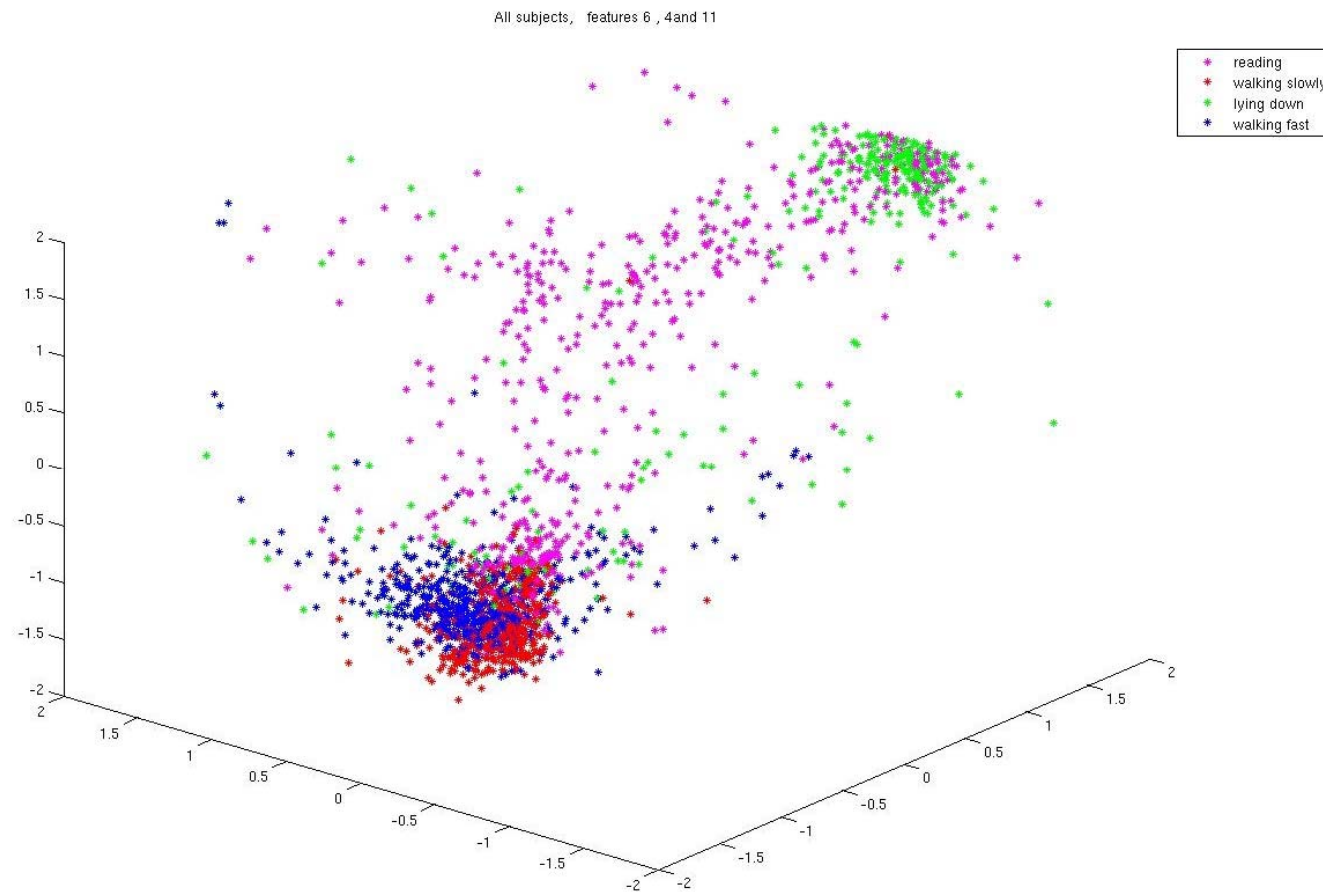




# Activity Recognition

## Results

- For all subjects clustering is still present

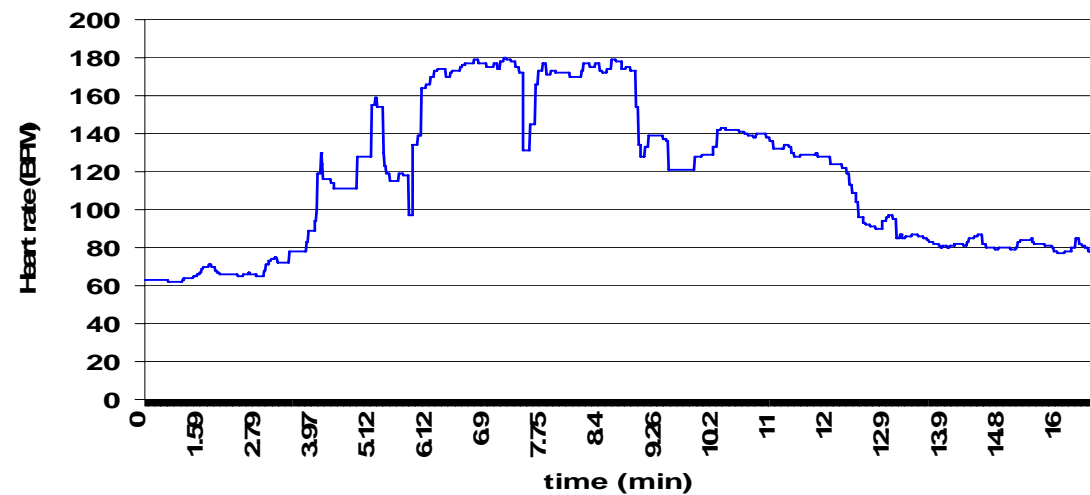
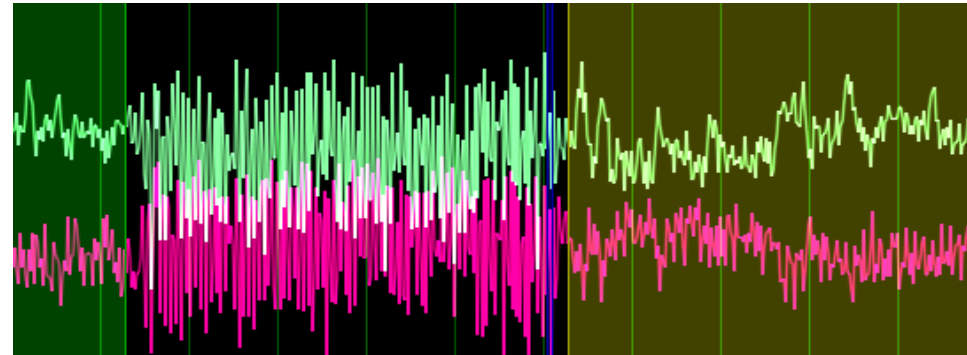





# Correlating Activity to Physiology

## Results

- A normal subject's recovery from exercise
  - Correlates well exercise
- In the case of anastomotic leak
  - Persistent  $\uparrow$ HR
  - Impaired mobility
  - Inactivity



# Future Challenges

- 
- **Reproducing results in post-op home setting**
    - Activity, Mobility, Physiology, Recovery
  - **Improving data analysis methods**
    - Multi-sensor fusion (several types of sensors)
    - Online Recognition methods
    - Assessing change in activity over time
    - Detecting sudden changes
  - **Improved usability & uptake**
    - Miniaturisation
    - Prolonging battery life
  - **Medical Infrastructure**

# Acknowledgements

## Pervasive Computing Team at Imperial

- Benny Lo
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Questions ?

