Wearable Sensing & Machine Learning for Smart Health

-- Recent Research Progress at USLab

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Outline

- Introduction to USLab
- Recent Scientific Research
  - Blood Glucose Monitoring Based on Smart Phone PPG Signals
  - Wrist Pulse Signal Processing & Lung Cancer Diagnosis
- International Collaboration
- Future Work

Ubiquitous Sensing Lab

- **12 graduate students (from 4 countries, 3 alumni) + 7 undergraduates (2014-2018)**

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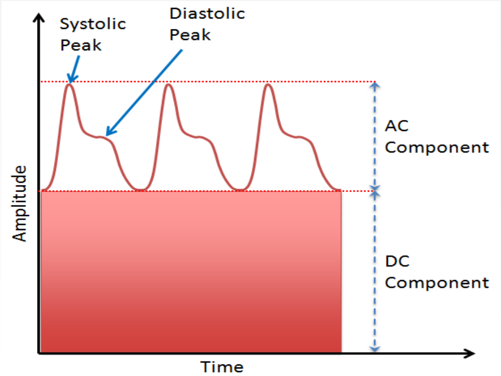

  - Wrist Pulse Signal Processing & Lung Cancer Diagnosis
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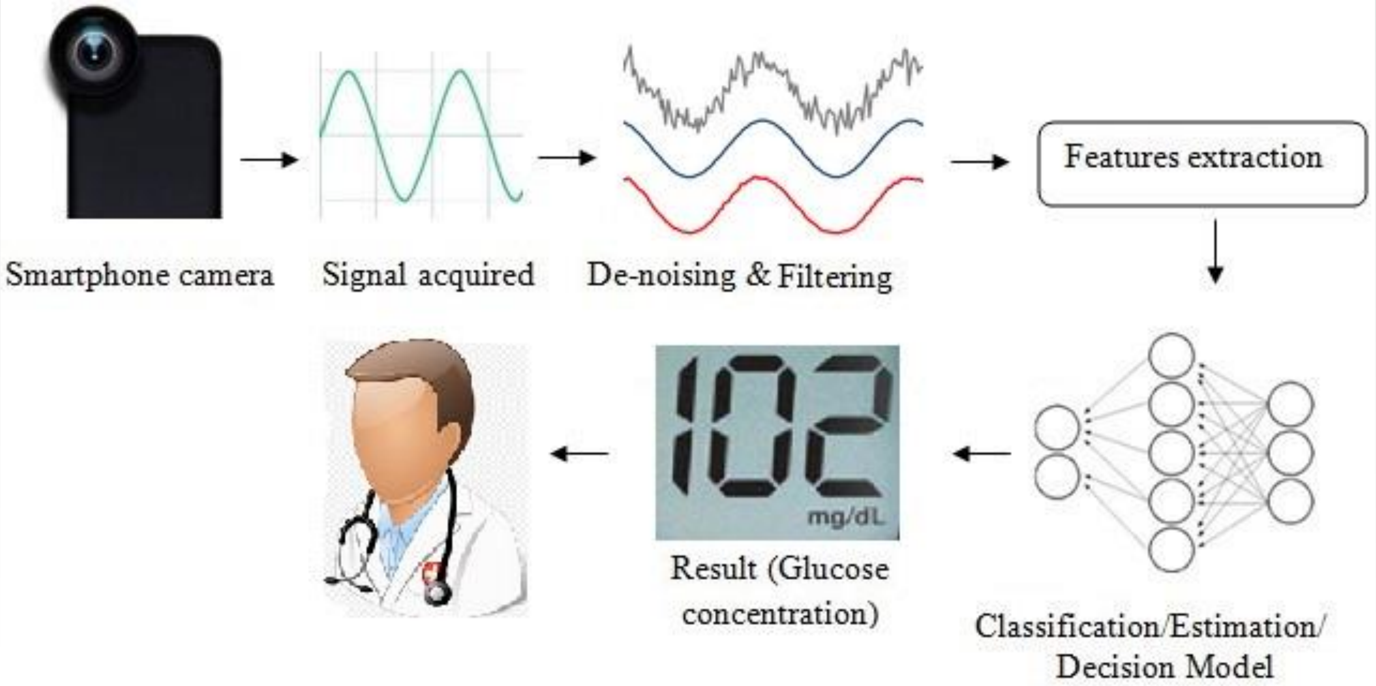
- Future Work

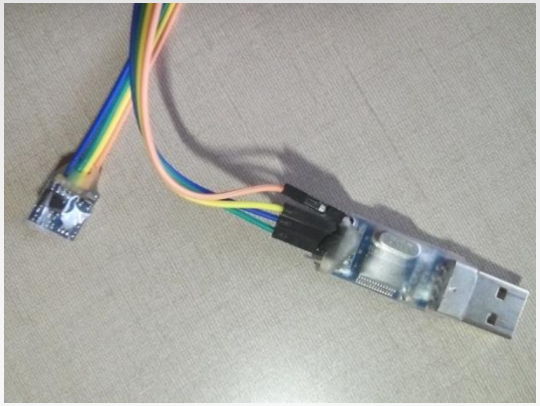
Blood Glucose Monitoring Based on Smart Phone PPG signals



- **Classification of valid and invalid samples**
  - **Only smartphone camera used to acquire the data**
- **Valid samples classified into 2 glucose groups**
  - **Painless, Cost effective, Portable, Simple**
  - **No need for individual re-calibration**

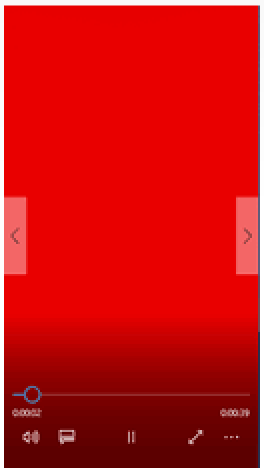
Groups	Blood Glucose Ranges (mmol/l)
G1	3.9–5.6
G2	5.7–7.2

Raw Data Acquisition



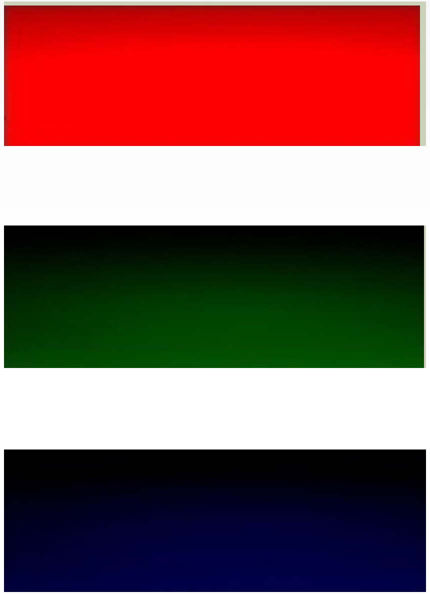
Lab-built PPG module

Video recording using smartphone camera



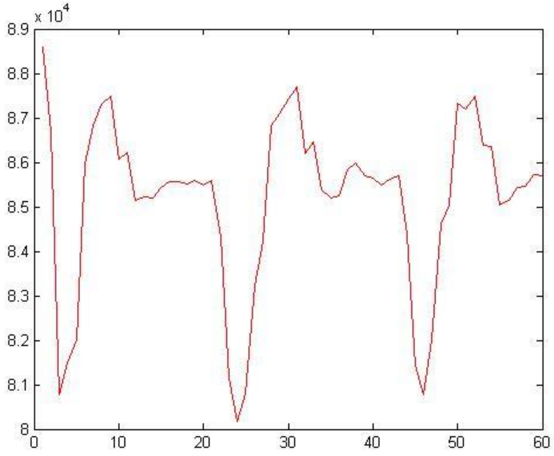
Recorded video

A video frame extracted

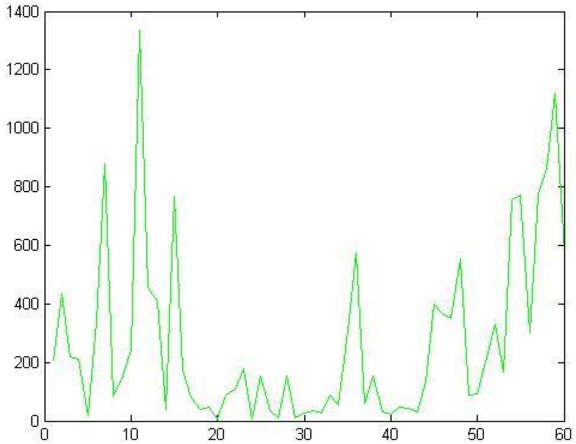


Red, Green and Blue components of the frame

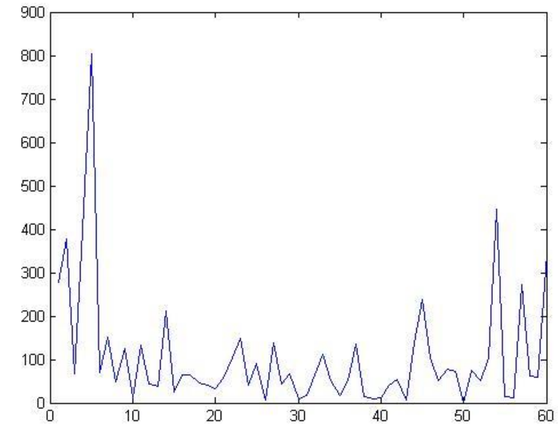
PPG Signal Extraction



PPG signals extracted
from the Red component

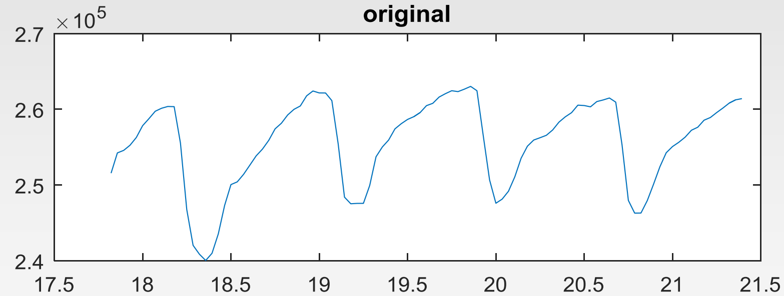


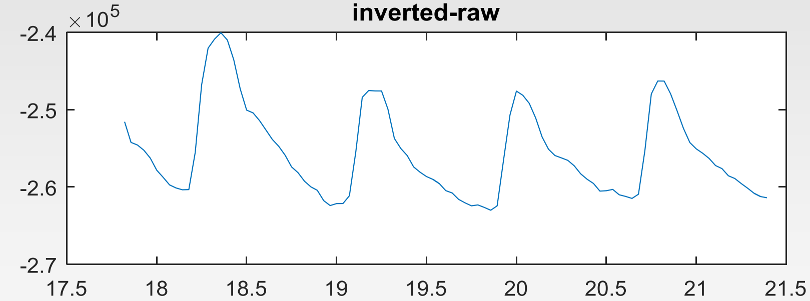
PPG signals extracted
from the Green component

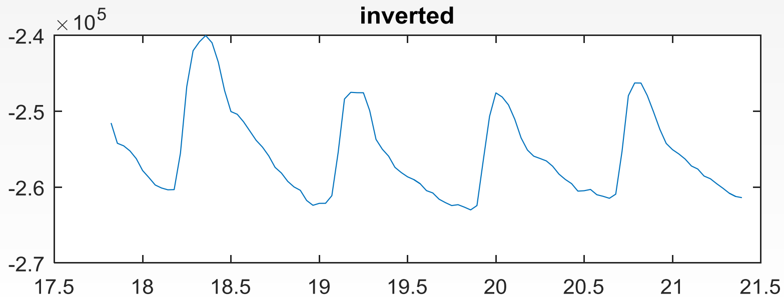


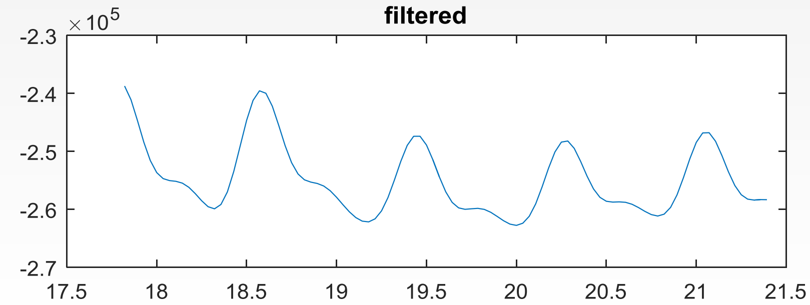
PPG signals extracted
from the Blue
component

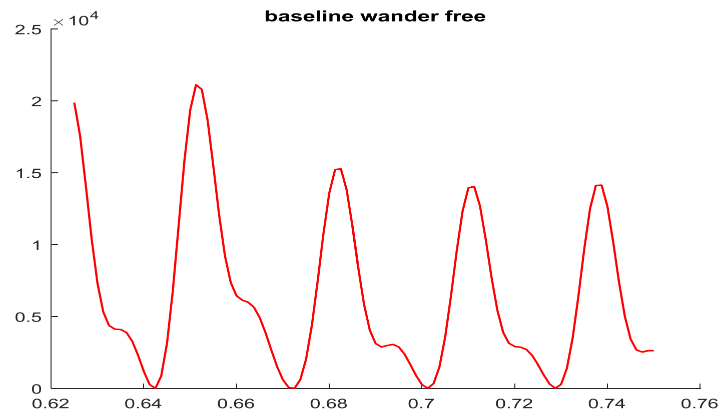
PPG Signal Processing



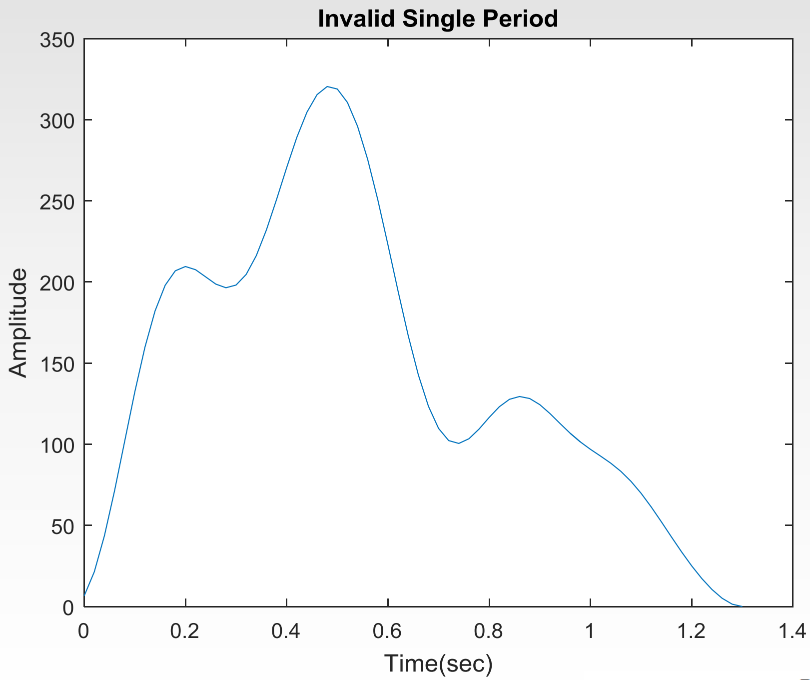


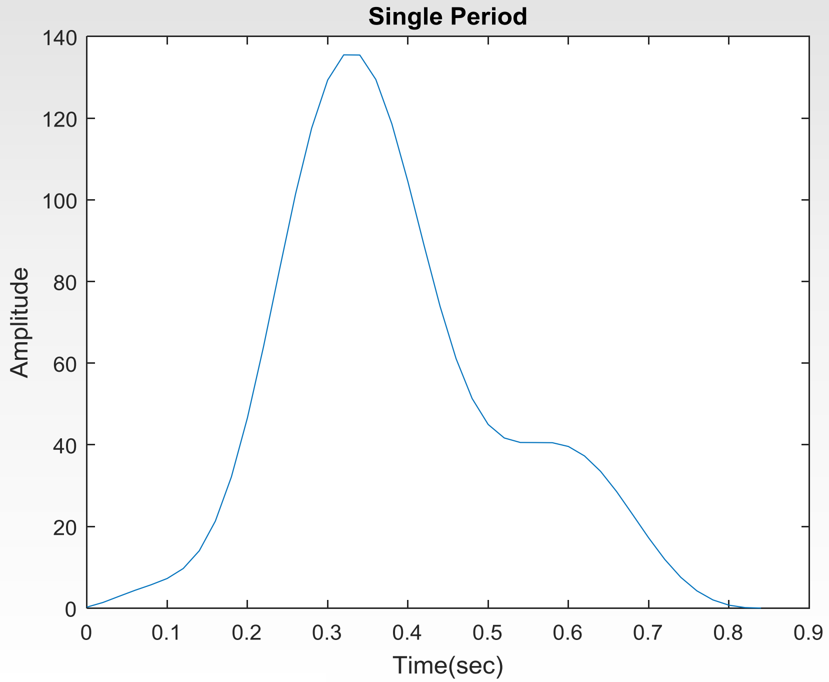


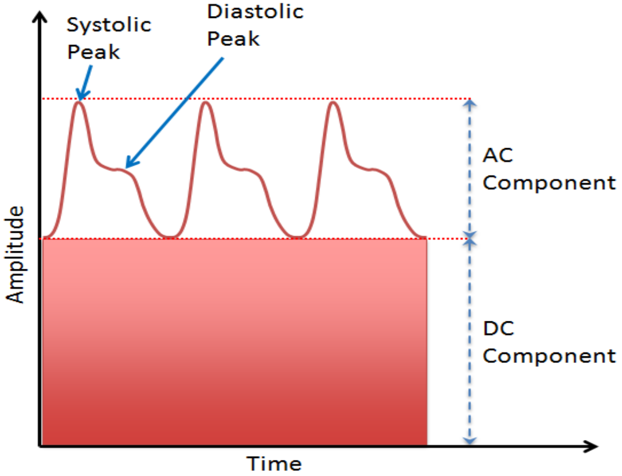




Classification of Valid and Invalid Samples

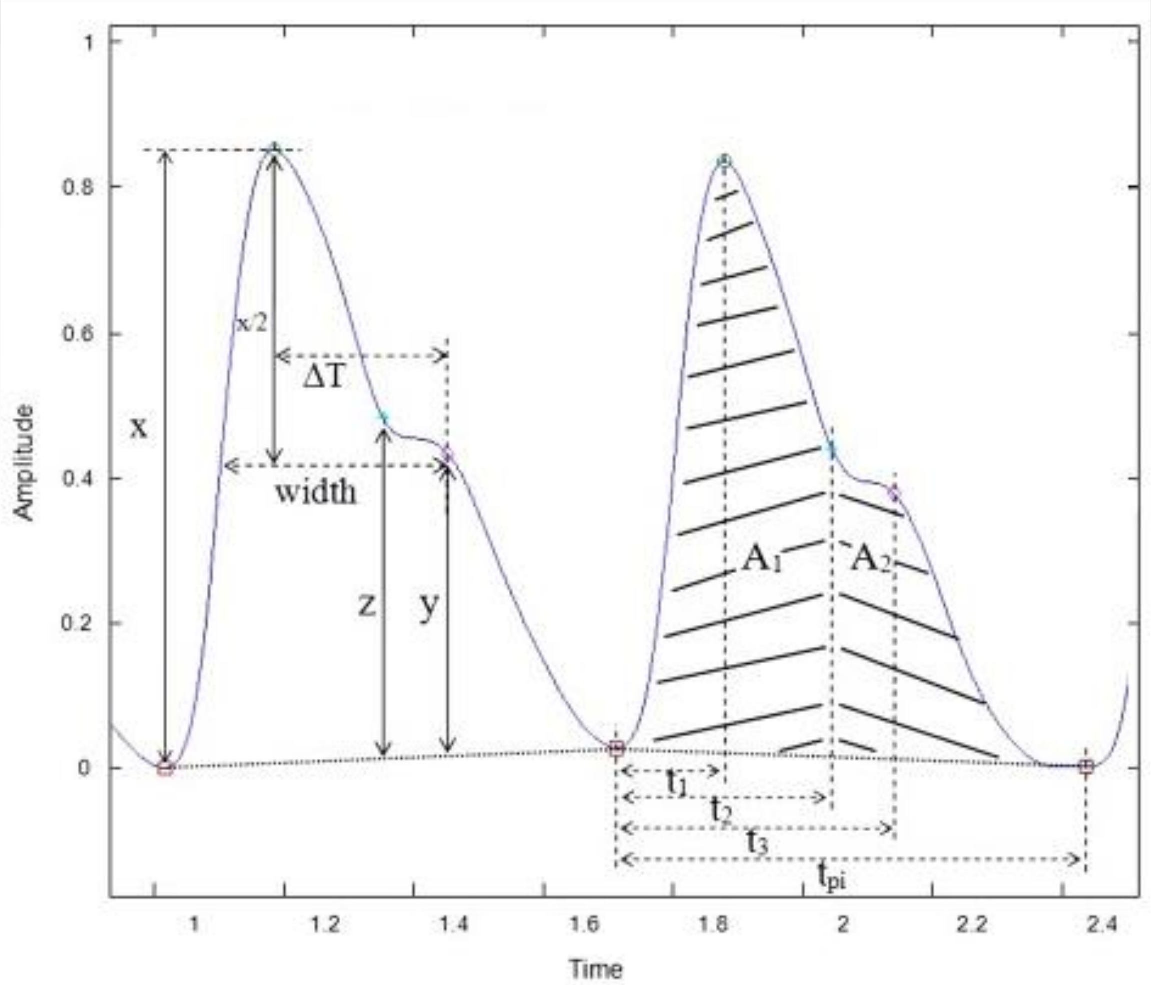






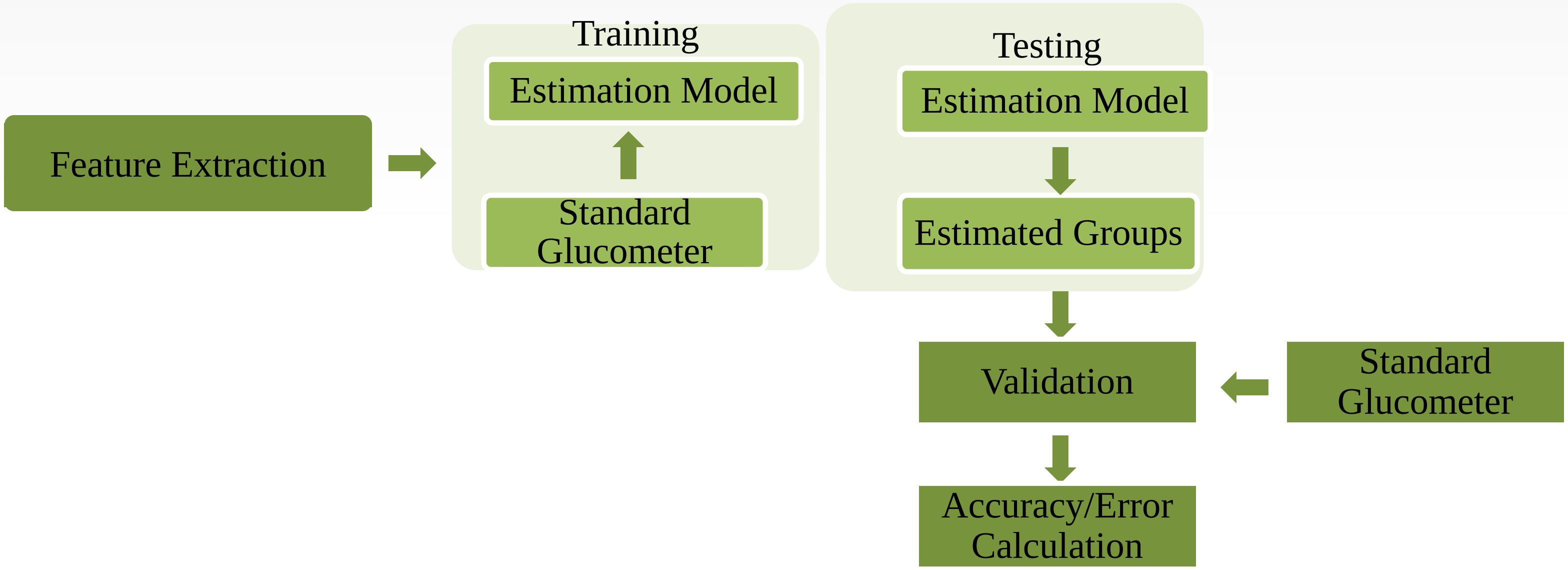
Feature Extraction

- **67 Features**



Glucose Group Classification

- **Classification using Subspace KNN**
  - **Feature-matrix for the dataset was divided into training and testing dataset randomly. 5-fold cross validation.**
  - **Bagged trees, RUS booster trees, Decision trees, and Subspace KNN**



Results

- The accuracy of invalid single period classification was found to be 98.2%.
- The overall training accuracy was found to be 86.2%.

Classifier	Overall Accuracy	Invalid Sample Classification
Subspace KNN	86.2%	98.2%
RUS Boosted Trees	85%	90.2%
Bagged Trees	86%	96.7%
Decision Trees	80.1%	83.6%

[1] Sarah Ali Siddiqui, Yuan Zhang*, Zhiquan Feng and Anton Kos, A Pulse Rate Estimation Algorithm Using PPG and Smartphone Camera, *Journal of Medical Systems* (Springer), vol. 40 (126), 2016. DOI: 10.1007/s10916-016-0485-6. (IF 2.456)
[2] Sarah Ali Siddiqui, Yuan Zhang*, Jaime Lloret, Houbing Song and Zoran Obradovic, Pain-free Blood Glucose Monitoring Using Wearable Sensors: Recent Advancements and Future Prospects, *IEEE Reviews in Biomedical Engineering*, 网络出版DOI 10.1109/RBME.2018.2822301.
[3] Sarah Ali Siddiqui, Yuan Zhang*, Chengyu Liu and Po Yang, Non-invasive Blood Glucose Estimation Using Smartphone PPG and Subspace KNN, *Computer Methods and Programs in Biomedicine* (Elsevier), under review.

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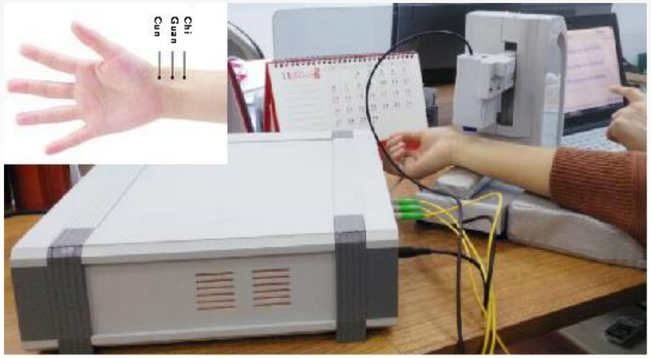
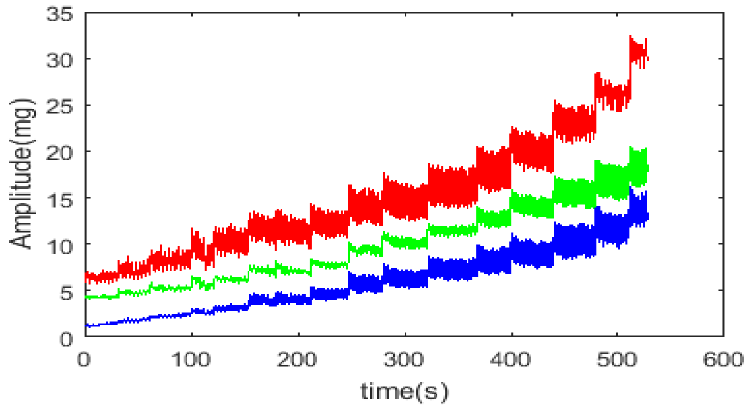
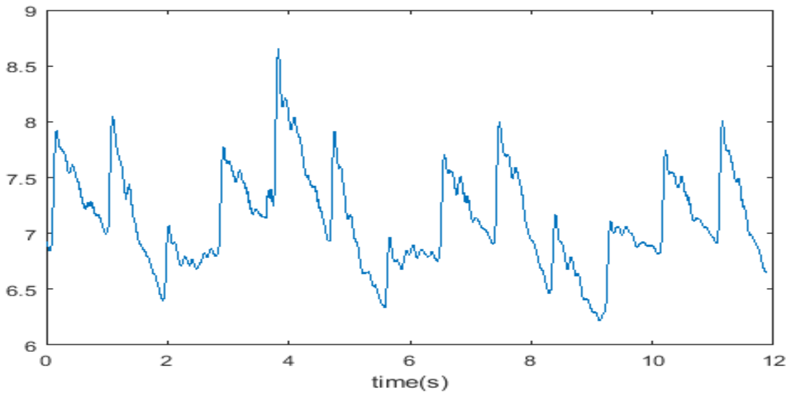


- International Collaboration
- Future Work

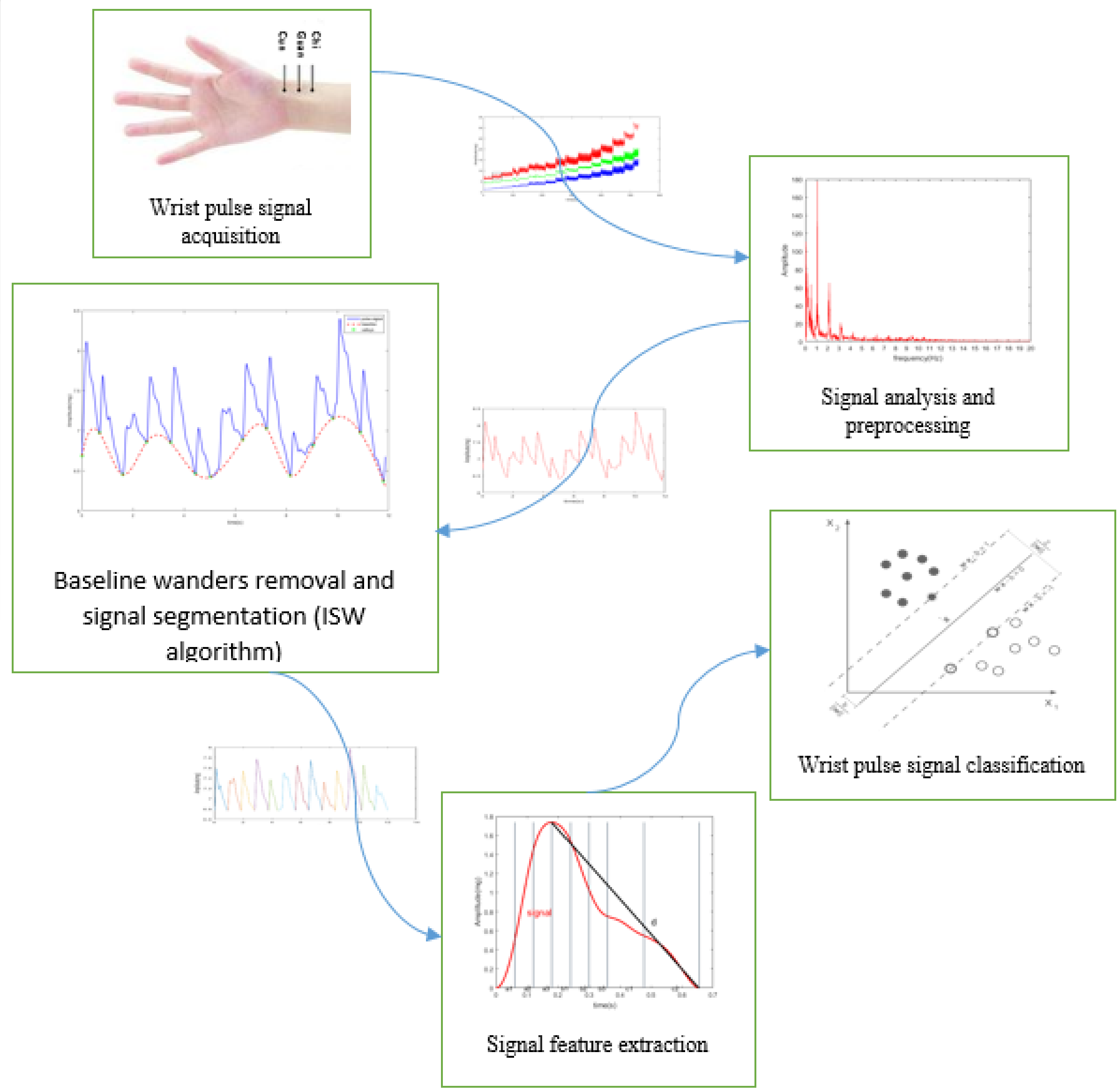
Wrist Pulse Signal Processing & Lung Cancer Diagnosis

- **Collaborate with Shandong Academy of Chinese Medicine**
- **Baseline Wander Removal & Segmentation**
  - **ISW**
- **Feature Extraction Based on Jin's Pulse Diagonosis**
  - **26 features**
- **Classification**



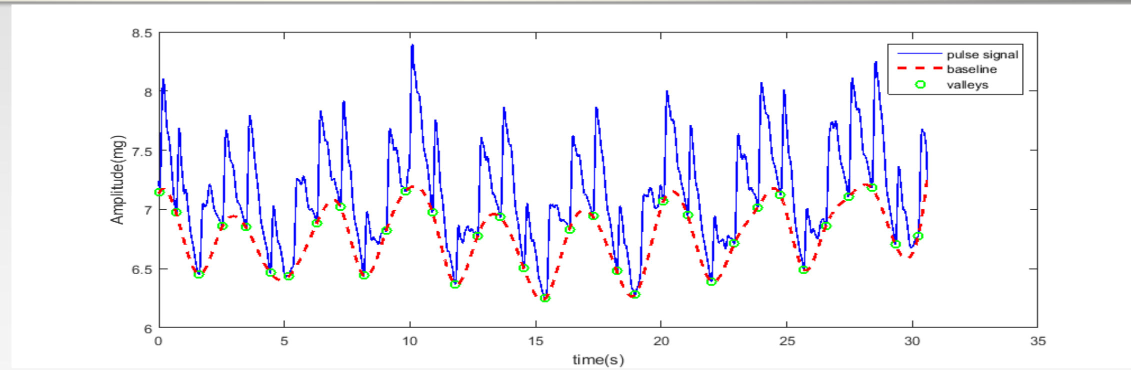


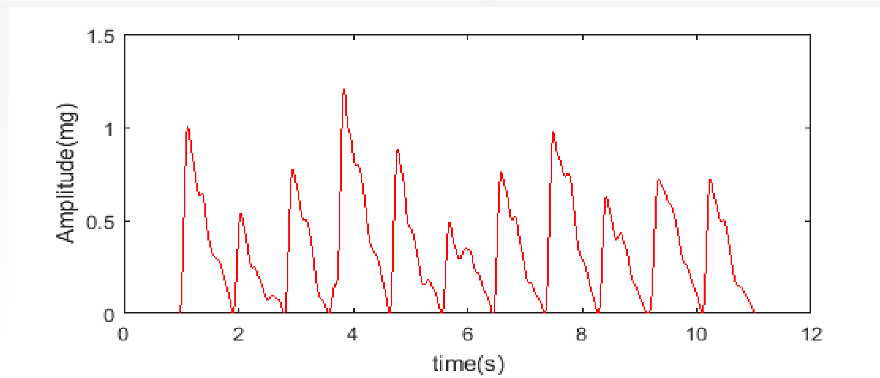
Wrist Pulse Signal Processing & Lung Cancer Diagnosis



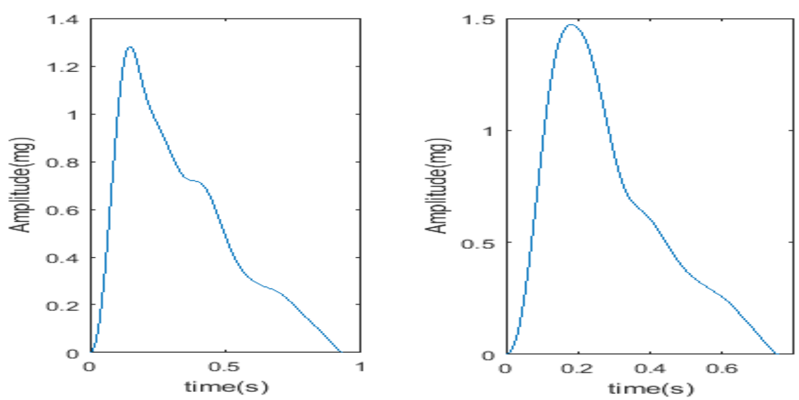
Wrist Pulse Signal Preprocessing

- **De-noising**
  - **Gaussian Filter**
- **Baseline Wander Removal**
- **Segmentation**

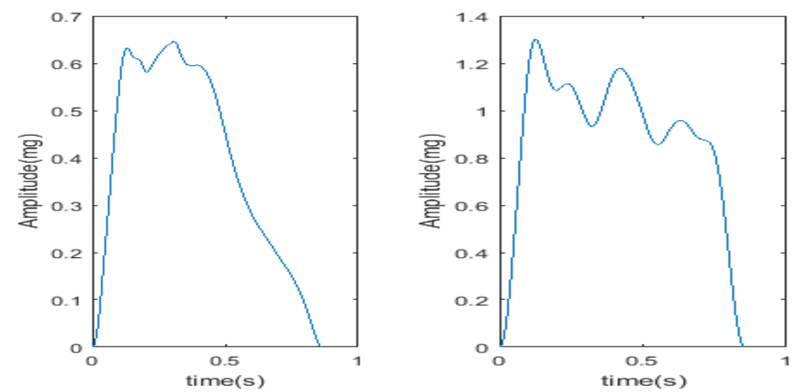




VALID PERIOD



INVALID PERIOD



Iterative Sliding Window

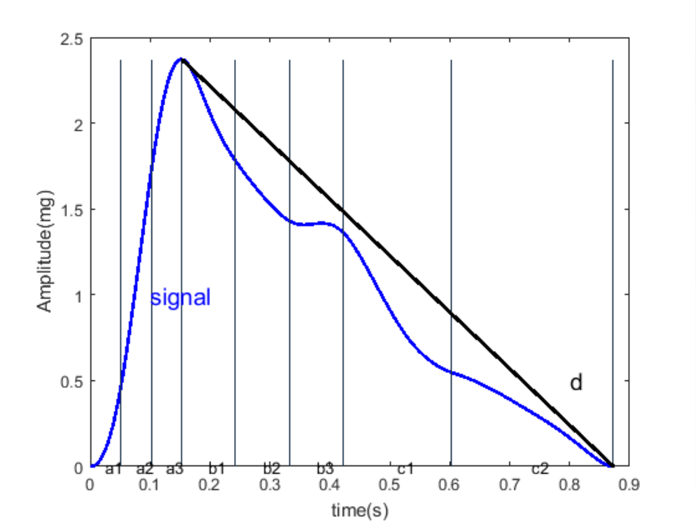
Pseudocode

- **Algorithm: iterative sliding window (ISW)**
- **Initial value: *n = 0; count = 0***
- **Get the main frequency *f* of the entire signal by using wavelet transform.**
- **Set a window with the size *Size* = 0.5*1/*f*.**
- **Slide the window to find the minimum of each window. The values of these local minima and their corresponding indexes are recorded as *y* and *x*.**
- **Fit the cubic spline function to the baseline *x* and *y*, and save the value in the array *baseline*.**
- **The number of points in *y* fitting *baseline-signal* < *0* is represented as *num*; If (*n* == *num*) *Count*++;**
- **Separate these points when the index is not continuous. Get the real minima *m* from the values with continuous indexes and find *e* in *y* that fits *e* = *min* (|*baseline-y*|). Replace *e* with *m*;**
- **(*x*, *y*) = Get_valley (*x*, *y*, *Size*). *n* = *num*;** →
- **Iterate steps 4-7, if *Count* < 10.**
- **Segment the signal according to *x*.**

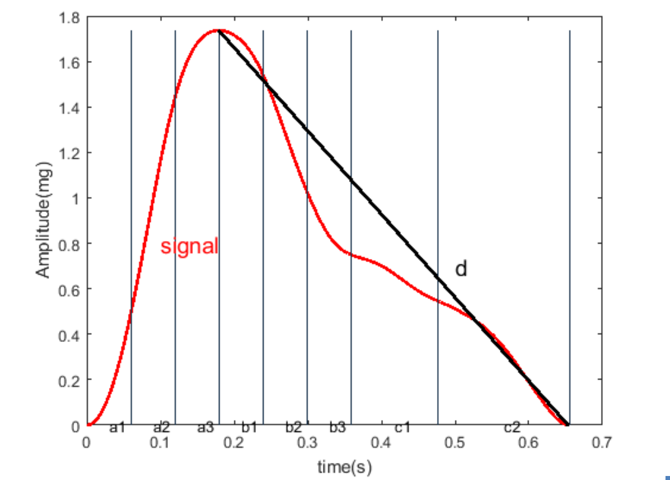
```
Get_valley function: to find real valleys
Input: Valley _index, Valley _value, Size
Initial value: mx = ones (3, n), n = length (Valley _value)
Output: Valley _x, Valley _y
mx (1, :) = Valley _index;
for i =2 : n
    if (mx (1, i) - mx (1, i-1) <= Size)
      if (i == 2 || mx (2, i-2) == 1)
         mx (2, i-1) = 0;
      end
    end
end
for i = 2 : n
    if (mx (2, i) == 1)
      if (mx (1, i) – mx (1, i-1) <= Size)
        mx (3, i) = 0;
      end
      else
         if (mx (2, i) == 0)
           mx (3, i) = 0;
         end
    end
Valleys_x = find (mx (3, :) == 1);
Valley_y = Valley_value (Valleys_x);
Return Valley_x, Valley_y;
```

JPD Based Feature Extraction

Signal of a healthy individual



Signal of a lung cancer patient



Definitions of features (12 key features)

pressure	depth of probe descent
ave_single	average value of the corresponding baseline
len_period	Length of the period
pmax_index	index of the maximum
num_09	number of the points fits maximum-minimum>= 0.9
ave_a1	average value of a signal in b1 clip
ave_a2	average value of a signal in b2 clip
ave_a3	average value of a signal in b3 clip
ave_b1	average value of a signal in c1 clip
ave_b2	average value of a signal in c2 clip
min_psub	distance between the peaks in heart slow-firing blood period
location	record the acquiring location within Cun, Guan, Chi

Classification

- **Training Set: 3871 Samples;**
- **Testing Set: 8508 Samples**
- **Classifiers:**
  - ***K* Nearest Neighbors (KNN)**
  - **Support Vector Machine (SVM)**
  - **Decision Tree**
  - **Discriminant**

Classifier	Diagnosis Accuracy
Linear SVM	78.13%
Coarse Gaussian SVM	71.88%
Fine KNN	84.38%
Cosine KNN	87.50%
Subspace discriminant	75.00%
Subspace KNN	87.25%
Simple tree	65.63%
Quadratic discriminant	90.63%

Classification

- **Comparison of classification accuracy of using the signals acquired from *Cun*, Guan, and Chi**

Classifier	Diagnosis Accuracy		
	Cun	Guan	Chi
Linear SVM	88.46%	80.00%	88.00%
Coarse Gaussian SVM	96.15%	88.00%	88.00%
Fine KNN	96.15%	68.00%	88.00%
Cosine KNN	96.15%	72.00%	88.00%
Subspace discriminant	88.46%	84.00%	76.00%
Subspace KNN	65.38%	64.00%	88.00%
Simple tree	73.08%	64.00%	84.00%
Quadratic discriminant	73.08%	76.00%	84.00%

[1] Zhichao Zhang, Yuan Zhang*, Lina Yao, Houbing Song* and Anton Kos, A Novel Wrist Pulse Signal Processing for Lung Cancer Recognition, *Journal of Biomedical Informatics* (Elsevier, IF 2.753), vol. 79, pp. 107-116, 2018. 中科院二区
[2] Zhichao Zhang, Xujie Zhuang, Yuan Zhang* and Anton Kos, Computerized Radial Artery Pulse Signal Classification for Lung Cancer Detection, *Proceedings of the 7th International Conference on Information Society and Technology*, Kopaonik, Serbia, vol. 1, pp. 275-278, March 2017.
[3] Zhichao Zhang, Yuan Zhang*, Wei Jin and Anton Kos, KPD Based Signal Preprocessing Algorithm for Pulse Diagnosis, *Proceedings of IEEE International Conference on Information and Knowledge in the Internet of Things 2016* (IIKI2016), Beijing, China, pp. 299-304, Oct 2016, DOI 10.1109/IIKI.2016.75.
[4] 张智超、庄须婕、梅贞、张远、金伟、罗贝尼，基于金氏脉学的脉搏波信号处理方法及肺癌检测系统，发明专利申请号 20171081152.4

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International Collaboration

- IEEE Senior Member, 2014.4- ; ACM senior member, 2016.5-

- *IEEE Access* Associate Editor, 2015.9-present
- *Internet of Things* (Elsevier) Associate Editor, 2018.6–present

- *IEEE Internet of Things Journal* SI on Wearable Sensor Based Big Data Analysis for Smart Health, (Leading Guest Editor) , in progress.
  - http://ieee-iotj.org/wp-content/uploads/2017/11/CFP-Wearable-Sensor-Based-Big-Data-Analysis-for-Smart-Health.pdf

- *Smart Health* (Elsevier) SI on Wearable Sensor Signal Processing for Smart Health, (Leading Guest Editor)，under production.
  - Yuan Zhang, Fatos Xhafa, Carolina Ruiz and Lina Yao, Special Section Editorial: Wearable Sensor Signal Processing for Smart Health, *Smart Health*, vol. 5-6, pp. 1-3, 2017. DOI 10.1016/j.smhl.2018.03.004.

International Collaboration

- *IEEE Access* SI on Big Data Analytics for Smart And Connected Health (Leading Guest Editor)
  - Yuan Zhang*, Lin Zhang, Eiji Oki, Nitesh V. Chawla and Anton Kos, Special Section Editorial: Big Data Analytics for Smart and Connected Health, IEEE Access, vol. 4, pp. 9906-9909, 2016, DOI: 10.1109/ACCESS.2016.2646158.

- *Annals of Telecommunications* (Springer) SI on Healthcare on Smart and Mobile Devices (Leading Guest Editor)
  - Health Care on Mobile Devices, Annals of Telecommunications, vol. 71(9), October 2016.

- *International Journal of Ad Hoc and Ubiquitous Computing* (InderScience) SI on Application-Oriented Protocol Design for Wireless Ad Hoc Networks (Leading Guest Editor)
  - Application-Oriented Protocol Design for Wireless Ad Hoc Networks, Int. J. of Ad Hoc and Ubiquitous Computing, vol. 16(1), 2014.

International Collaboration

- **TPC Chair**
  - **IEEE/ACM Big Data Analytics for Smart and Connected Health 2016/2017/2018 (BIGDATA4HEALTH 2016/2017/2018), http://www.bigdata4health.org**
- **TPC Member**
  - **10+ international conferences including InfoCom, ICC, GlobeCom, MASS, SmartComp, etc**
- **Reviewer**
  - **30+ top-tier journals of the IEEE, Elsevier, Springer, ACM, InderScience, Weily, etc.**
- **Invited talks**
  - **Department of Computer Science, Georgia State University, USA**
  - **Faculty of Electrical Engineering, University of Ljubljana, Slovenia**
  - **Department of Computer Science, University of Otago, New Zealand**

International Collaboration

- **In recently years Dr. Yuan Zhang has formally collaborated with international colleagues from 10+ countries including USA, United Kingdom, Slovenia, Canada, New Zealand, Australia, Spain, Pakistan, Korea, Chile, Serbia, Bangladesh, etc**
  - **More details available at http://uslab.ujn.edu.cn/index.html。**
  - ***IEEE Internet of Things Journal* SI on Wearable Sensor Based Big Data Analysis for Smart Health (Leading Guest Editor).**
    - **Roozbeh Jafari @ Texas A&M University, USA**
    - **Jinsong Wu @ Universidad de Chile, Chile**
    - **Winston Seah @ Victoria University of Wellington, New Zealand**
    - **Joel J.P.C. Rodrigues @ National Institute of Telecommunications, Brazil**
    - **Yunchuan Sun @ Beijing Normal University, China**

International Collaboration

- **China-UK Young Researcher Bilateral Workshop on Mental Health Technologies, NSFC- British Council (UK)**
  - **Collaborated with Benny Lo (Imperial College London)**
  - **Setp 7-9, Jinan, China**
- **Objectives of the workshop:**
  - **Promote the research in mental health technologies and support the growth of the field;**
  - **Discuss the challenges in mental healthcare and opportunities for technologies to improve the care of mental illnesses;**
  - **Facilitate new collaborations between China and UK institutions;**
  - **Establish data and knowledge sharing strategies between institutions and countries;**
  - **Facilitate collaborations with industries, hospitals, and NGOs.**

International Collaboration

- **Four Mentors**

Prof Guang-Zhong Yang (Fellow of the Royal Academy of Engineering, UK; Chinese National Recruitment Programme of Global Experts千人计划)

Prof Bin Hu (Chinese National Recruitment Program of Global Experts千人计划)

Prof Tom Denning (Executive Director of Cambridgeshire & Peterborough NHS Foundation Trust)

Prof Tianzi Jiang (Changjiang Scholars Program长江学者)

International Collaboration

- **Participants**
  - **China side: 18 young researchers from 10+ universities/institutions**
  - **UK side: under recruitement**
- **Some Guests**
  - **Aiguo Song (宋爱国), Dean of School of Instrument Science & Engineering, Southeast Univ.**
  - **Jianqing Li (李建清), Vice President of Nanjing Medical Univ.**
  - **Hongen Liao (廖洪恩, Chinese National Recruitment Program), Dept. of Biomedical Engineering, Tsinghua Univ.**
  - **Dahong Qian (钱大宏, Chinese National Recruitment Program), School of Translational Medicine, Zhejiang Univ.**
  - **Liqang Nie (聂礼强, Chinese National Recruitment Program for the Youth), School of Computer Science & Technology, Shandong Univ.**
  - **Huansheng Ning (宁焕生), Vice Dean of School of Computer & Communication Engineering, Univ. of Science and Technology Beijing**
  - ……

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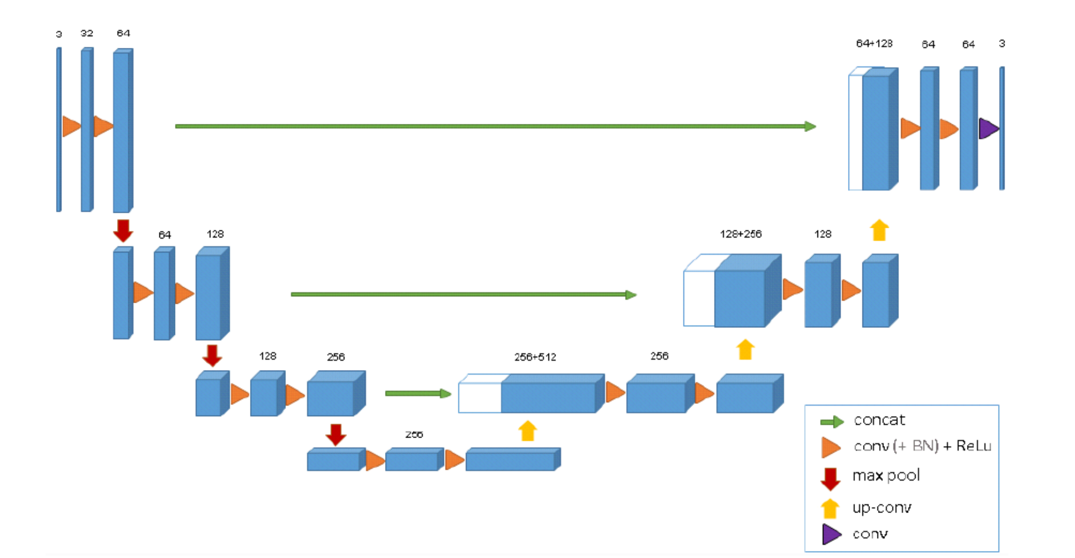
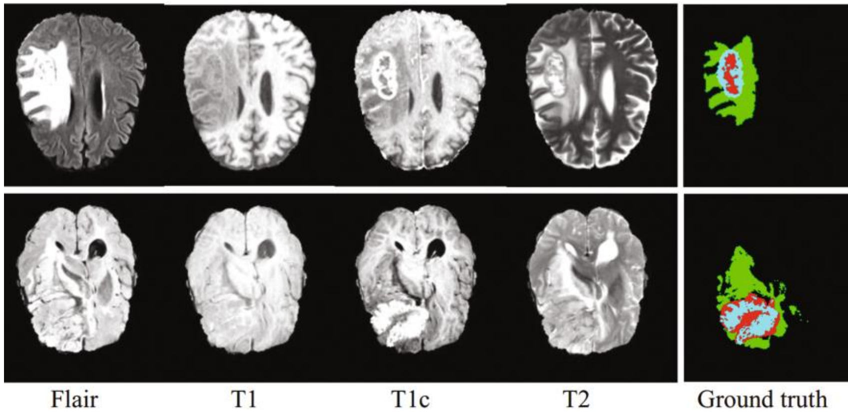
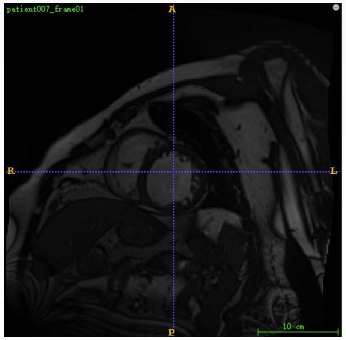
MRI Image Analysis Using 3D U-Net for Automatic Brain Tumor Segmentation

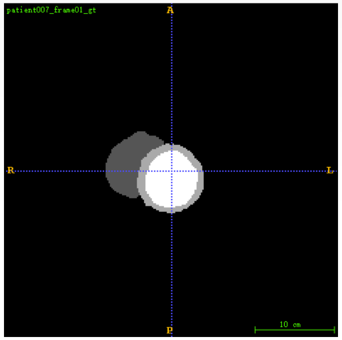
- Among brain tumors, gliomas are the most common and aggressive, leading to a very short life expectancy.
- Goal: To find a deep learning approach to segment glioma MRI images automatically with high accuracy.
- Method: 3D U-Net extended from the previous U-Net architecture.



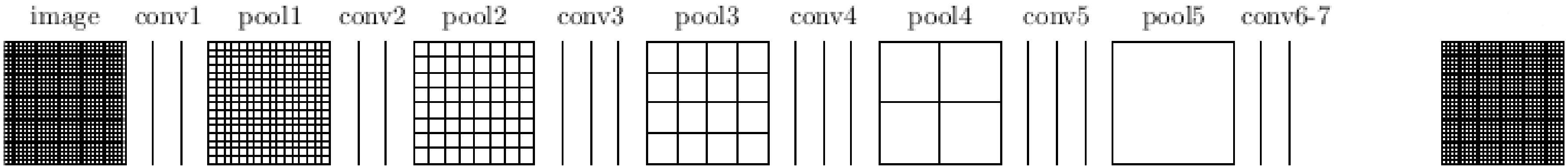


- **Cardiac MRI is considered as gold standard in cardiac disease diagnosis especially in left ventricular (LV) and right ventricular (RV) function estimation.**
- **Goal: a new approach to segment LV, RV and myocardium**
  - **Preprocessing: data augment, Wiener filtering**



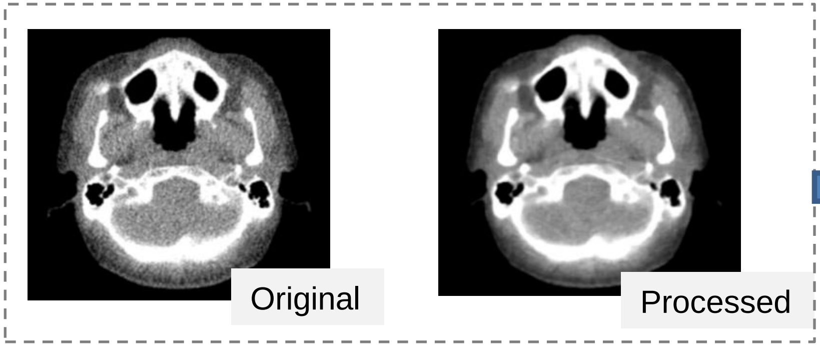


  - **Segmentation: Fully Convolutional Networks**

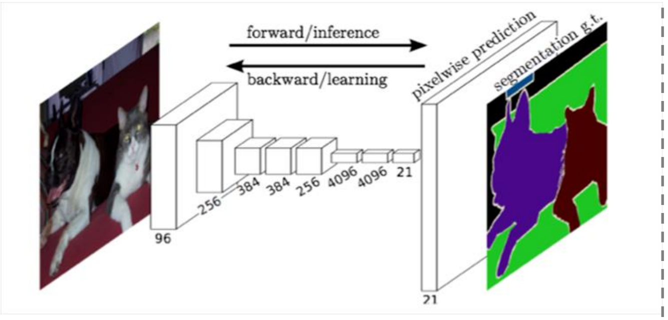


Segmentation of Parotid Gland in MVCT Using Deep Learning

- **In radiotherapy for nasopharyngeal cancer, the essential step of analyzing the parotid gland is to segment the parotid gland in MVCT.**
- **Goal: Propose a deep learning approach to segment parotid gland in MVCT automatically with high accuracy.**
- **Method：**
  - **Using deep learning method, segment parotid gland in processed MVCT images, and extract parotid gland in original images.**
  - **Find the correlation between texture feature, volume, and clinical symptoms.**



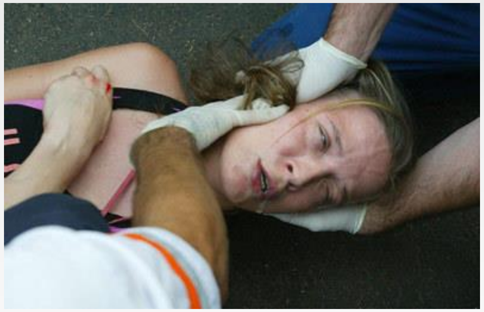
Dictionary learning



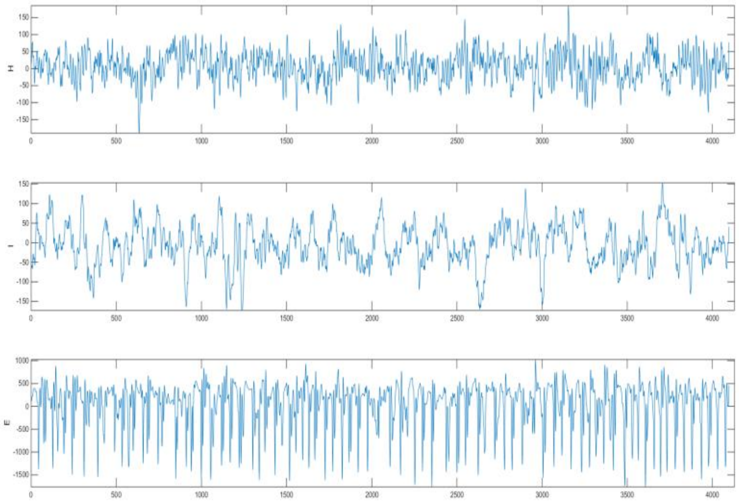
FCN

Epilepsy Detection and Prediction Based on Wearable EEG

- **Epilepsy Detection**
  - **Lightweight & efficient algorithm**
  - **Design reasonable method to extract features, select the most prominent features.**
  - **Multi-Classification algorithm**

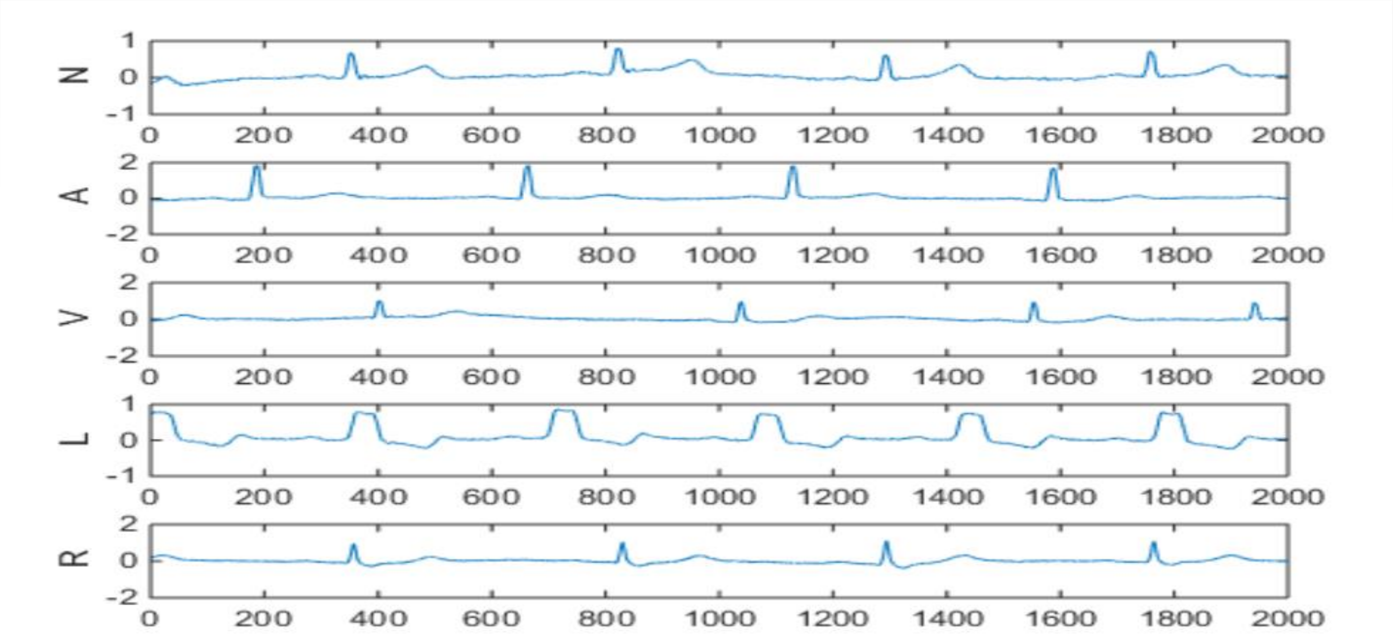


- **Epilepsy Prediction**
  - **Cooperate with Qilu Children's Hospital**



- **Emotiv EPOC APP**

- **Goal: To find a deep learning approach to classify different types of ECG beats automatically.**
- **Method: A deep convolutional neural network (CNN) for cardiac arrhythmias classification**



Thanks