

АНАЛИЗ СИГНАЛОВ СЕНСОРНЫХ УСТРОЙСТВ

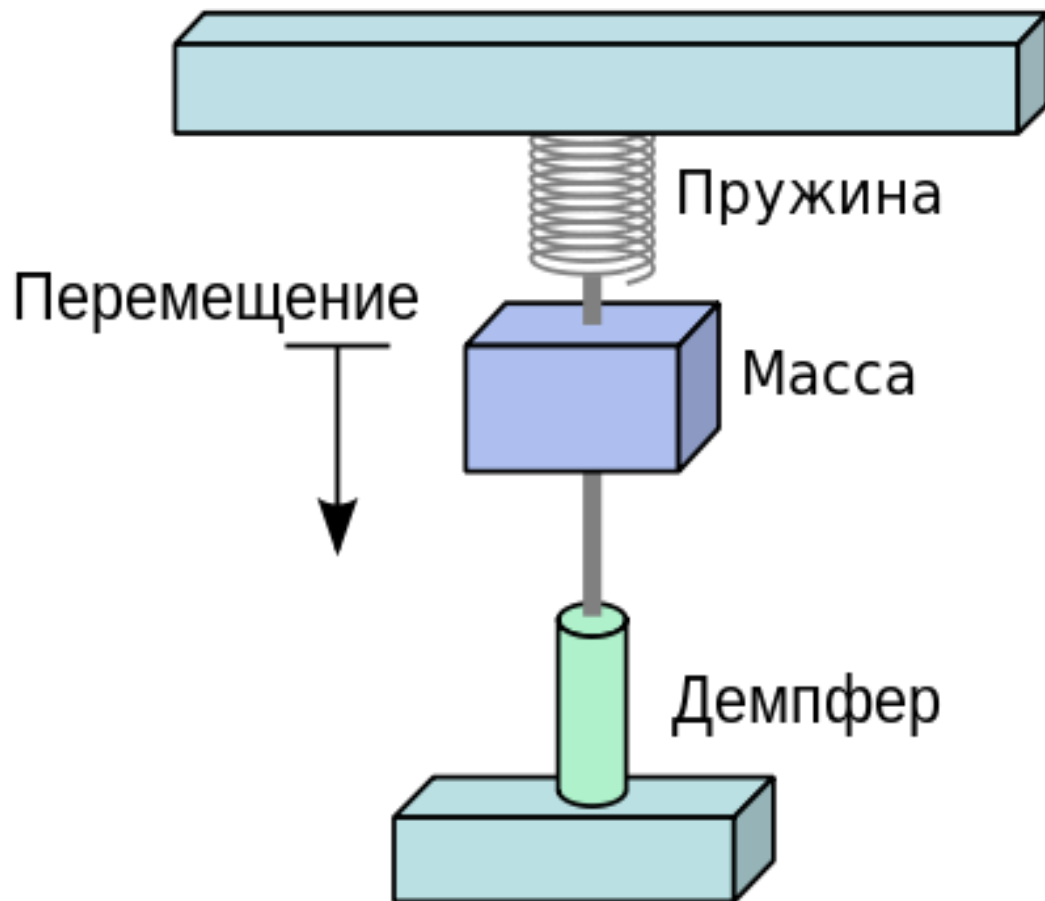


Андрей Остапец

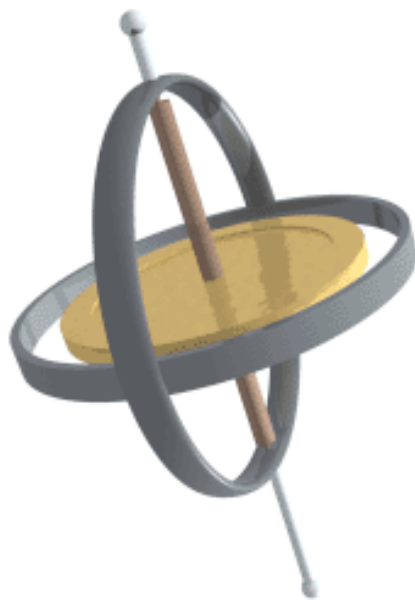
План

- **Введение**
 - Акселерометр и гироскоп
 - Распознавание действий пользователей
- **РАМАР2**
- **Общая схема распознавания**
- **Применение на конкретных задачах**

Акселерометр

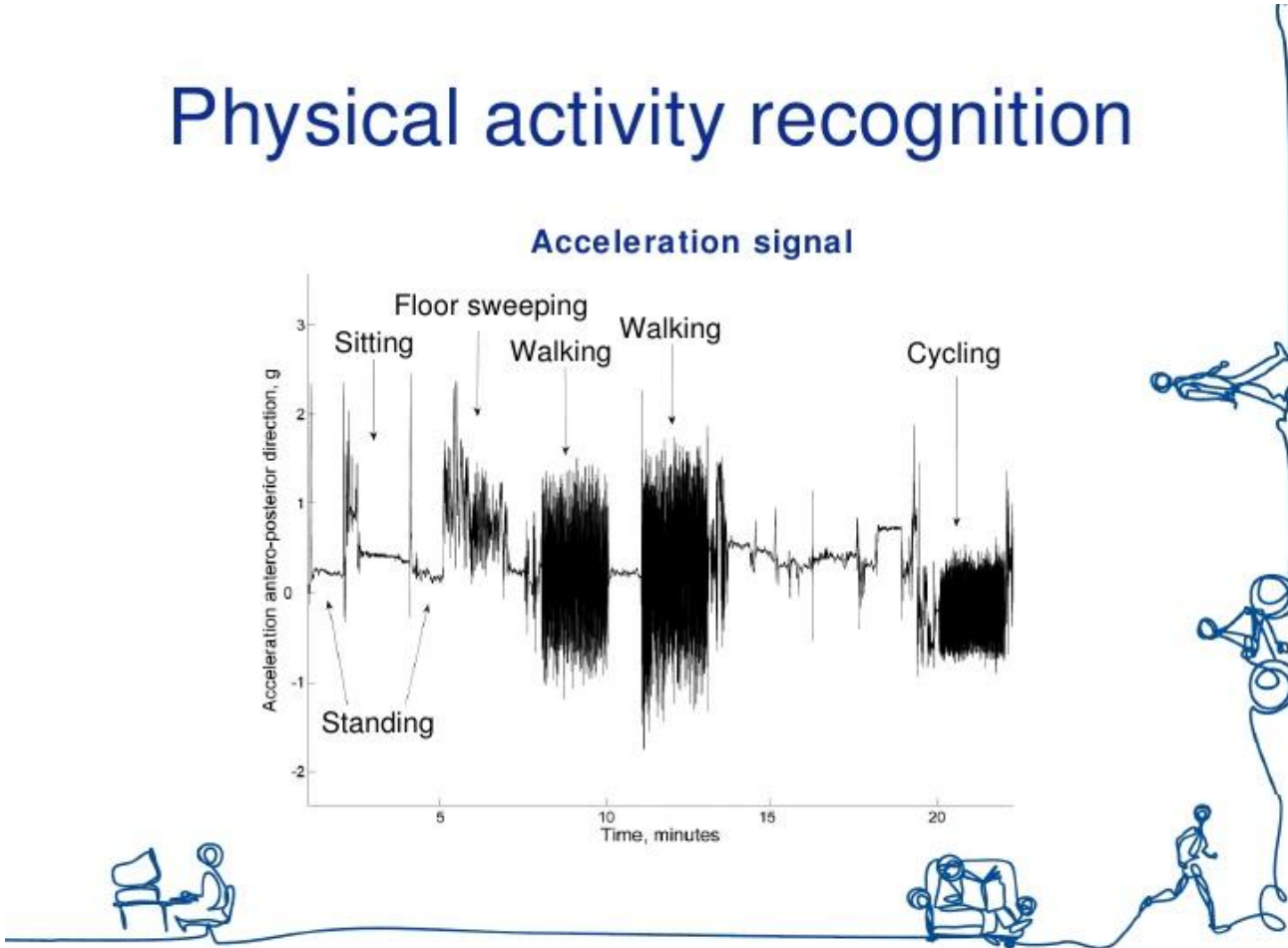
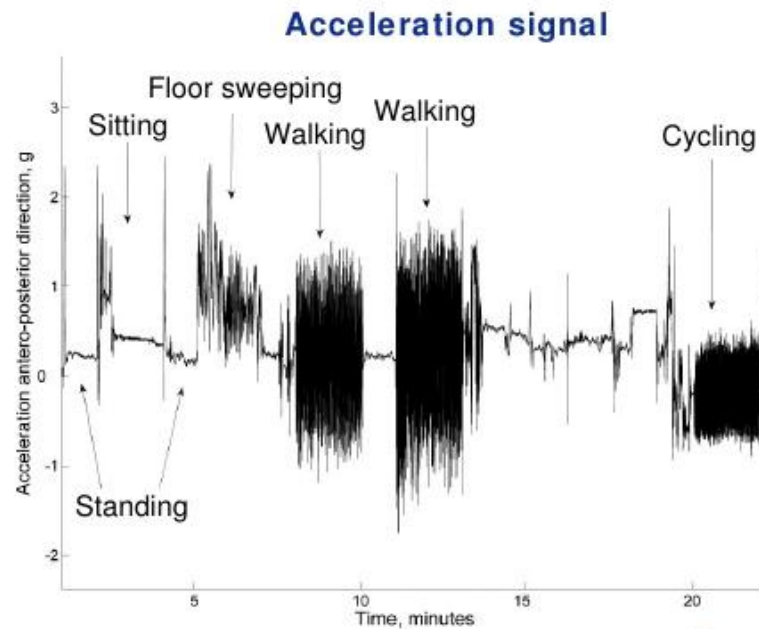


Гироскоп



Распознавание действий пользователей

Physical activity recognition



PAMAP2

Abstract: The PAMAP2 Physical Activity Monitoring dataset contains data of 18 different physical activities, performed by 9 subjects we

Data Set Characteristics:	Multivariate, Time-Series	Number of Instances:	3850505	Area:	Computer
Attribute Characteristics:	Real	Number of Attributes:	52	Date Donated	2012-08-06
Associated Tasks:	Classification	Missing Values?	Yes	Number of Web Hits:	3407

Source:

Attila Reiss, Department Augmented Vision, DFKI, Germany, attila.reiss '@' dfki.de
Date: August 2012.

Data Set Information:

The PAMAP2 Physical Activity Monitoring dataset contains data of 18 different physical activities (such as walking, cycling, playing soccer, heart rate monitor). The dataset can be used for activity recognition and intensity estimation, while developing and applying algorithms of c

** Sensors **

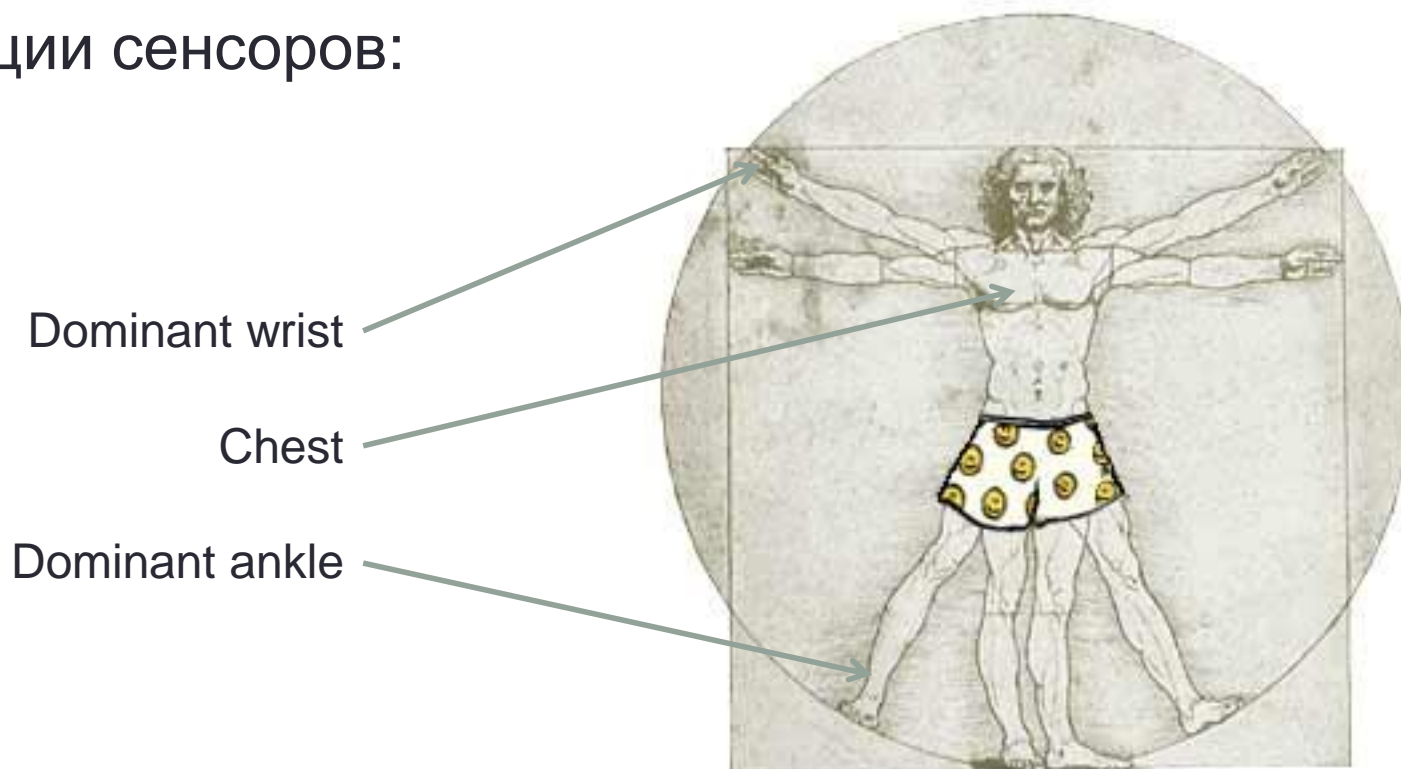
3 Colibri wireless inertial measurement units (IMU):

- sampling frequency: 100Hz
- position of the sensors:
 - 1 IMU over the wrist on the dominant arm
 - 1 IMU on the chest

<http://archive.ics.uci.edu/ml/datasets/PAMAP2+Physical+Activity+Monitoring>

РАМАР2 - Sensors

- Данные за 10 часов: акселерометр, гироскоп, магнитометр, термометр
- Три позиции сенсоров:



PAMAP2 - Activities

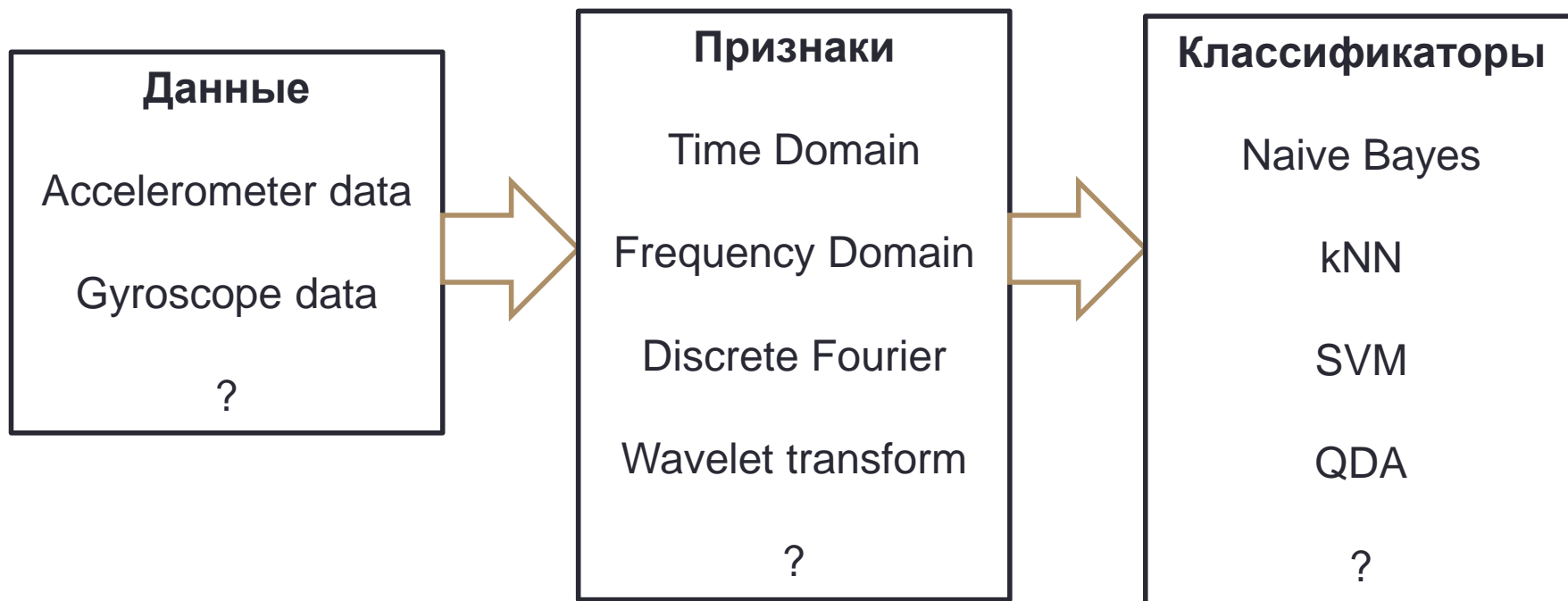


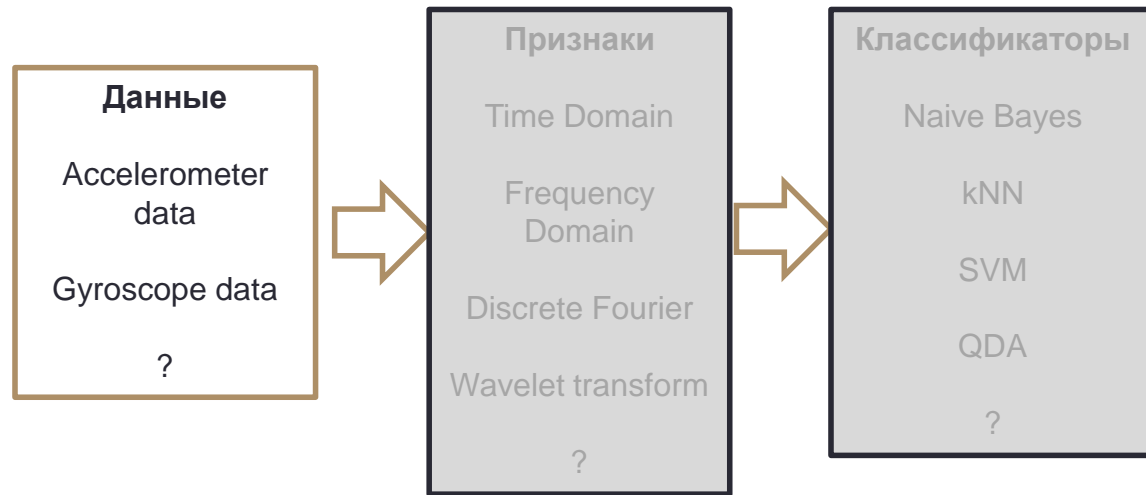
PAMAP2 - Data

Subject ID	Sex	Age (years)	Height (cm)	Weight (kg)	Resting HR (bpm)	Max HR (bpm)	Dominant hand
101	Male	27	182	83	75	193	right
102	Female	25	169	78	74	195	right
103	Male	31	187	92	68	189	right
104	Male	24	194	95	58	196	right
105	Male	26	180	73	70	194	right
106	Male	26	183	69	60	194	right
107	Male	23	173	86	60	197	right
108	Male	32	179	87	66	188	left
109	Male	31	168	65	54	189	right

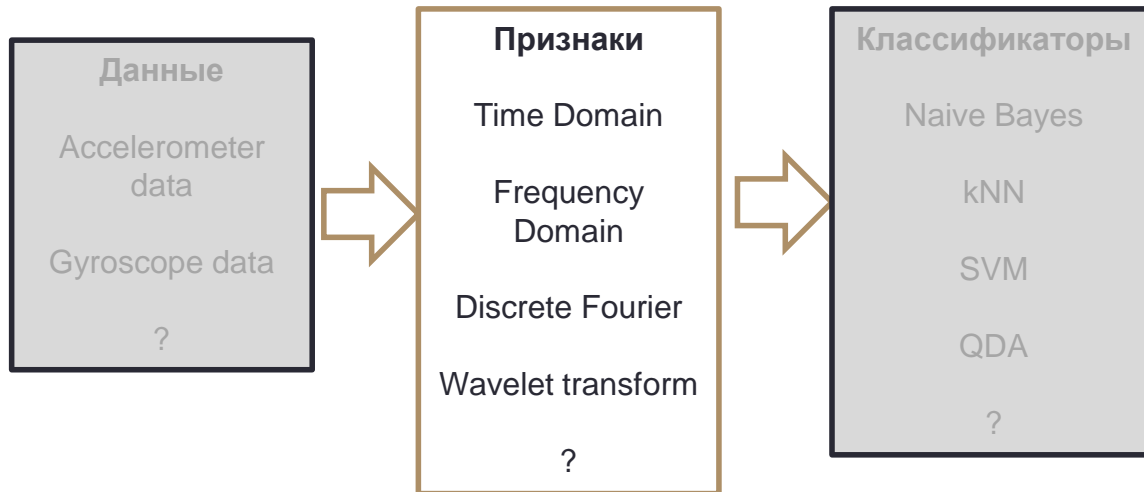
	subject101	subject102	subject103	subject104	subject105	subject106	subject107	subject108	subject109	Sum	Nr. of subjects
1 – lying	271.86	234.29	220.43	230.46	236.98	233.39	256.1	241.64	0	1925.15	8
2 – sitting	234.79	223.44	287.6	254.91	268.63	230.4	122.81	229.22	0	1851.8	8
3 – standing	217.16	255.75	205.32	247.05	221.31	243.55	257.5	251.59	0	1899.23	8
4 – walking	222.52	325.32	290.35	319.31	320.32	257.2	337.19	315.32	0	2387.53	8
5 – running	212.64	92.37	0	0	246.45	228.24	36.91	165.31	0	981.92	6
6 – cycling	235.74	251.07	0	226.98	245.76	204.85	226.79	254.74	0	1645.93	7
7 – Nordic walking	202.64	297.38	0	275.32	262.7	266.85	287.24	288.87	0	1881	7
9 – watching TV	836.45	0	0	0	0	0	0	0	0	836.45	1
10 – computer work	0	0	0	0	1108.82	617.76	0	687.24	685.49	3099.31	4
11 – car driving	545.18	0	0	0	0	0	0	0	0	545.18	1
12 – ascending stairs	158.88	173.4	103.87	166.92	142.79	132.89	176.44	116.81	0	1172	8
13 – descending stairs	148.97	152.11	152.72	142.83	127.25	112.7	116.16	96.53	0	1049.27	8
16 – vacuum cleaning	229.4	206.82	203.24	200.36	244.44	210.77	215.51	242.91	0	1753.45	8
17 – ironing	235.72	288.79	279.74	249.94	330.33	377.43	294.98	329.89	0	2386.82	8
18 – folding laundry	271.13	0	0	0	0	217.85	0	236.49	273.27	998.74	4
19 – house cleaning	540.88	0	0	0	284.87	287.13	0	416.9	342.05	1871.83	5
20 – playing soccer	0	0	0	0	0	0	0	181.24	287.88	469.12	2
24 – rope jumping	129.11	132.61	0	0	77.32	2.55	0	88.05	63.9	493.54	6
Labeled total	4693.07	2633.35	1743.27	2314.08	4117.97	3623.56	2327.63	4142.75	1652.59	27248.27	
Total	6957.67	4469.99	2528.32	3295.75	5295.54	4917.78	3135.98	5884.41	2019.47	38504.91	

Общая схема

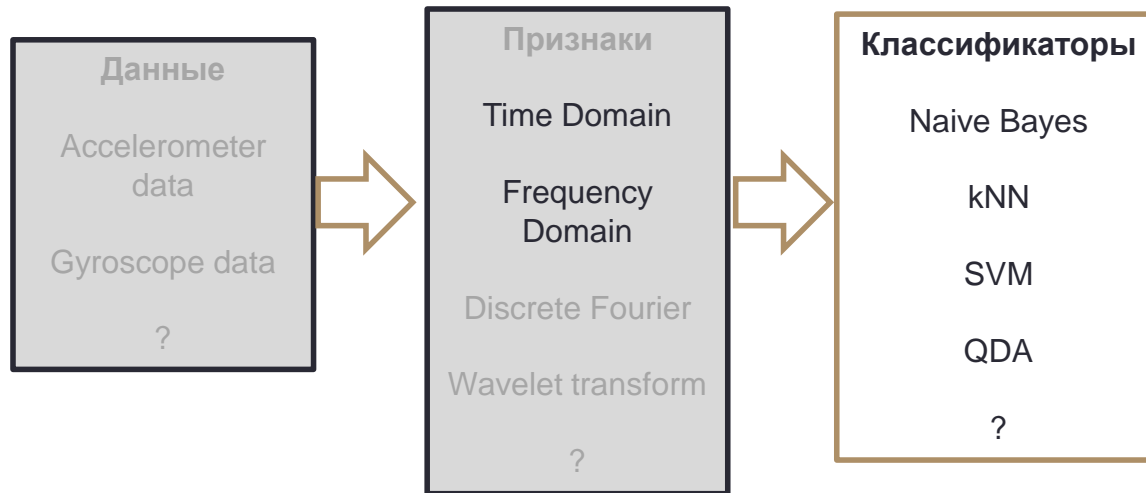




- Большинство решений используют только данные акселерометра.
- Проблема определения ориентации телефона в пространстве



- 50% перекрывающиеся окна
- Удаление шума из сигналов
- Корреляция между сигналами
- Discrete Fourier Transform
- Wavelet transform

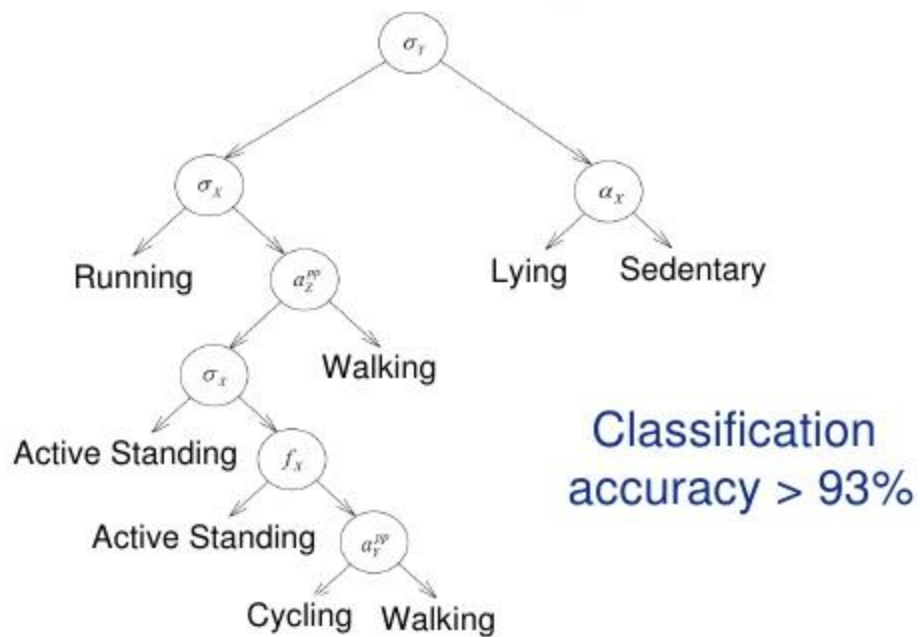


- Популярны C4.5 decision trees, Naive Bayes и kNN
- General-purpose vs user-specific
- HMM(Mannini & Sabatini)

Decision tree

Physical activity recognition

Decision tree model



Recognizing Human Activities Userindependently on Smartphones Based on Accelerometer Data

Pekka Siirtola and Juha Röning



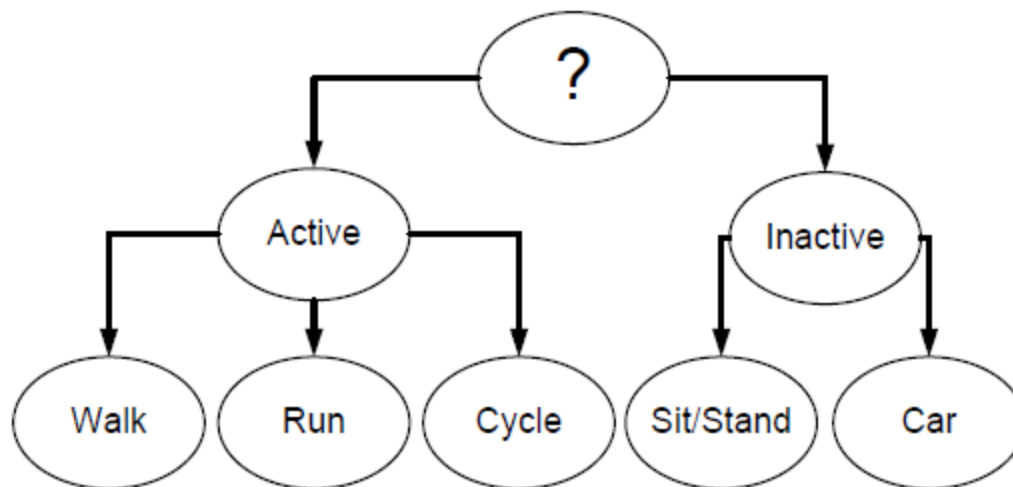
Данные

- Частота дискретизации 40 Hz
- В обучении:
 - 8 человек
 - Возраст от 25 до 34 лет (средний 29 лет)
 - Рост от 1.65 до 1.90 м (средний 1.78 м)
- Real-time classification:
 - 7 человек (3 новых)
 - Возраст от 27 до 34 лет (средний 30 лет)
 - Рост от 1.65 до 1.90 м (средний 1.75 м)
- 5 действий:
 - *walking*,
 - *cycling*,
 - *running*,
 - *idling (=sitting/standing)* ,
 - *driving/riding a car*

Признаки

- Переход от 3 осей к общему ускорению и ускорению на оси x и z
- Разбитие на окна(300 наблюдений, примерно 7.5 сек)
 - В обучении пересечение между соседними окнами 75 наблюдений
 - В контроле пересечение между соседними окнами 150 наблюдений
- 21 признак:
 - standard deviation,
 - mean, minimum, maximum,
 - five different percentiles (10, 25, 50, 75 and 90)
 - sum and square sum of observations above/below certain percentile (5, 10, 25, 75, 90 and 95).

Схема обучения



Отбор признаков - Sequential Forward Selection (SFS)

Результаты

THE RESULTS OF ONLINE RECOGNITION ON DEVICE USING NOKIA N8 AND KNN

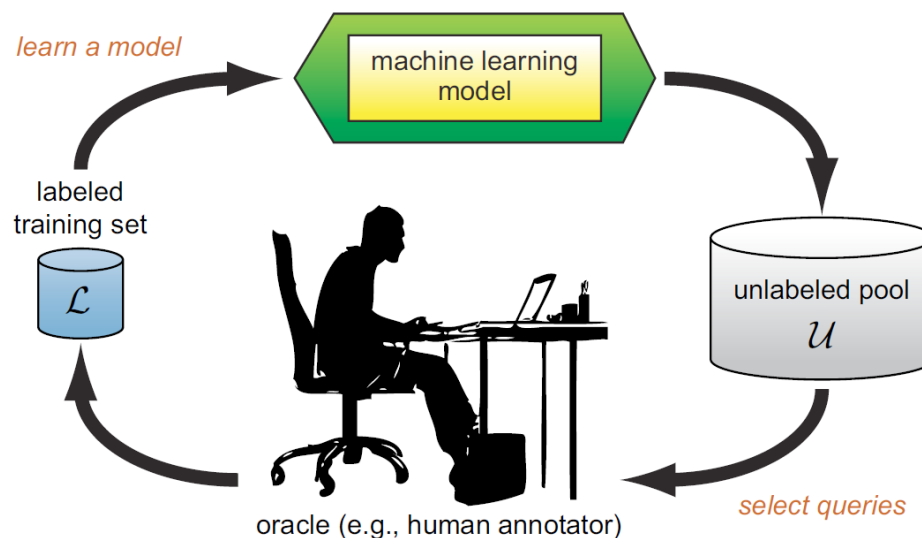
SUBJECT/ ACTIVITY	IDLING	WALKING	CYCLING	DRIVING	RUNNING	AVERAGE
SUBJECT 1	91.5%	99.9%	89.2%	91.4%	87.2%	91.8%
SUBJECT 2	99.9%	99.9%	93.7%	87.8%	92.4%	94.7%
SUBJECT 3	76.3%	99.9%	89.6%	-	92.8%	89.7%
SUBJECT 4	-	-	-	97.6%	-	97.6%
SUBJECT 5	95.6%	99.9%	89.5%	89.4%	97.9%	94.5%
SUBJECT 6	94.1%	99.9%	93.8%	-	99.9%	96.9%
SUBJECT 7	83.3%	99.8%	98.1%	-	99.9%	99.4%

Active Learning

- Данные
 - Смартфон: **HTC EVO 4G**
 - Сенсор: 3D accelerometer, 50 Hz
 - Телефон в кармане джинсов
 - 3 человека, 5 действий: ходьба, ходьба по лестнице вверх/вниз, бег, прихрамывание
- Генерация признаков (Всего 31 признак)
 - Размер окна: 256 наблюдений (5.12 сек)
 - Time Domain
 - Frequency Domain

Active Learning

Можно достичь хорошей точности с маленьким количеством тренировочных образцов, если выбирать данные на которых обучаемся



- **Motivation:** Минимизация времени и усилий для разметки обильных данных

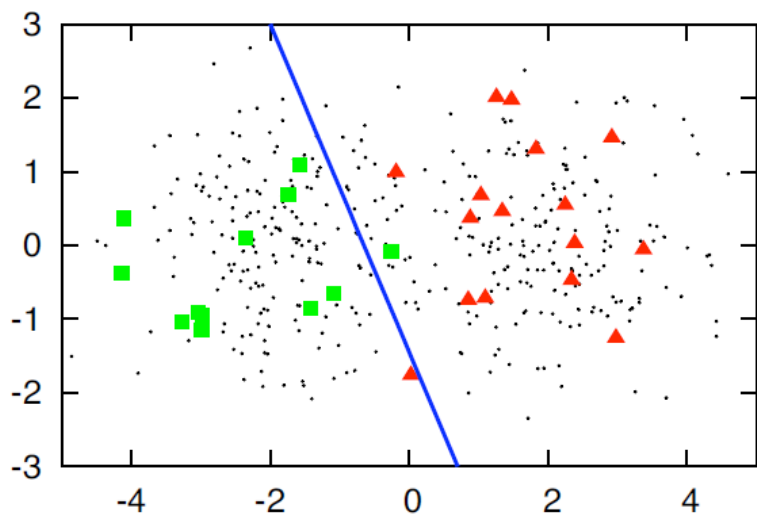
Методы

- Методы классификации
 - Quadratic discriminant analysis
 - K-Nearest Neighbors
 - Support Vector Machines
- Стратегии запроса для неразмеченного образца
 - Quadratic: Расстояние до кривой
 - KNN: Энтропия
 - SVM: Расстояние до кривой

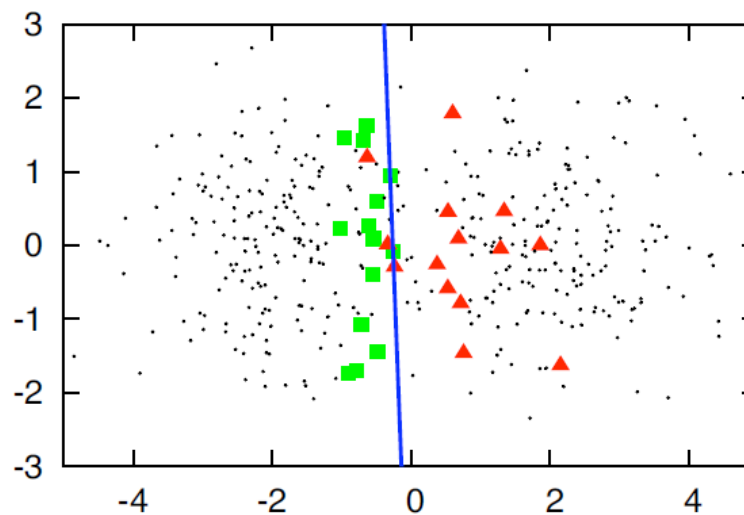


Query Strategy: Distance Measure

Запрос выполняется для неразмеченного образца, ближайшего к разделяющей кривой



Random Query

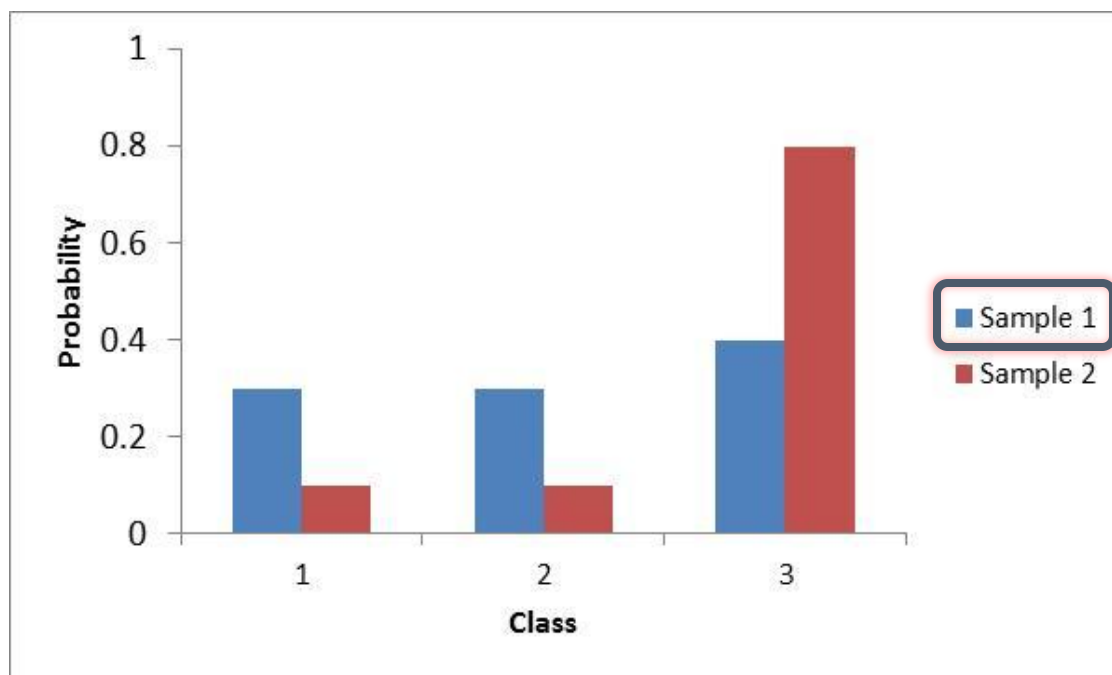


Active Query

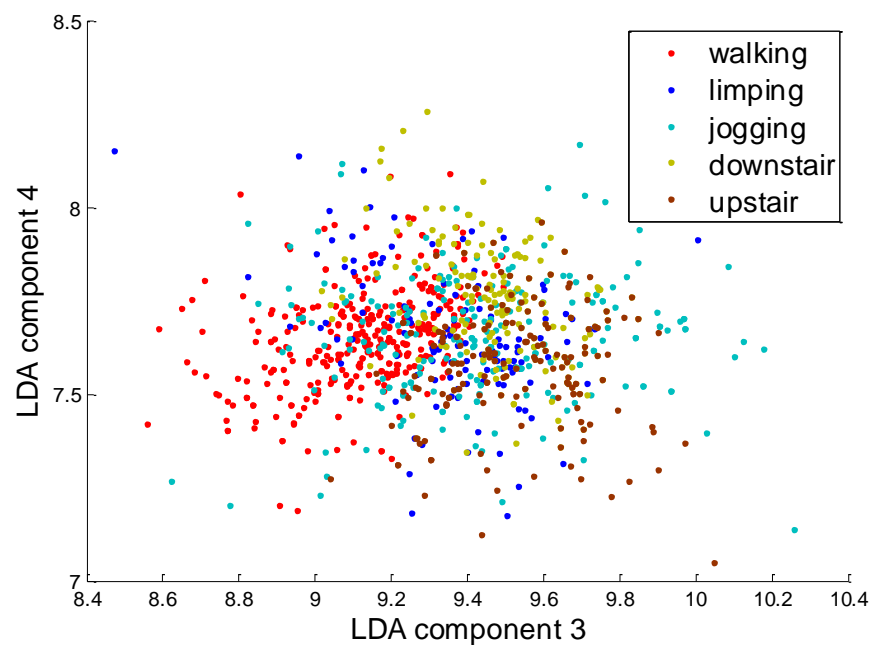
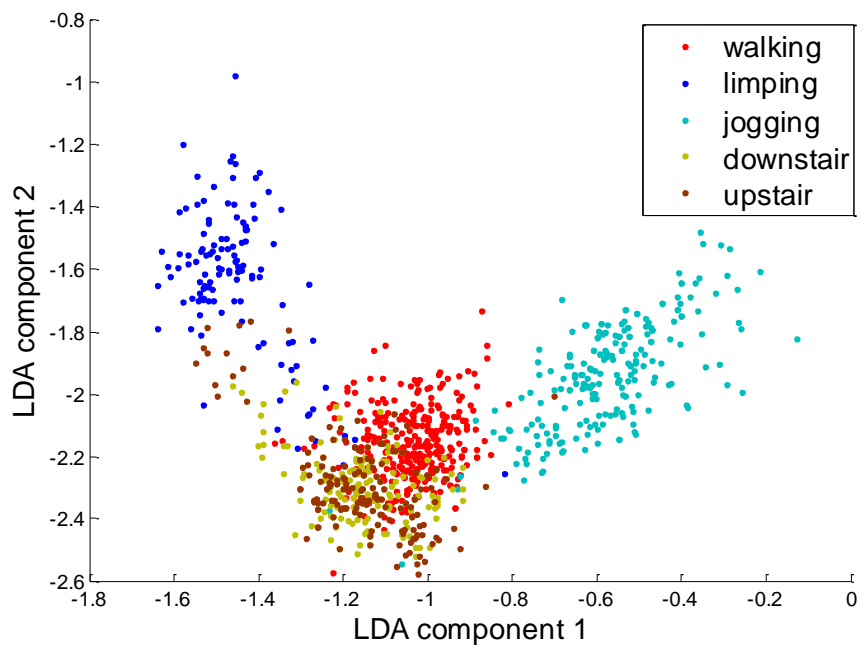
Query Strategy: Entropy Measure

Запрос выполняется для неразмеченного экземпляра, который имеет максимальную энтропию:

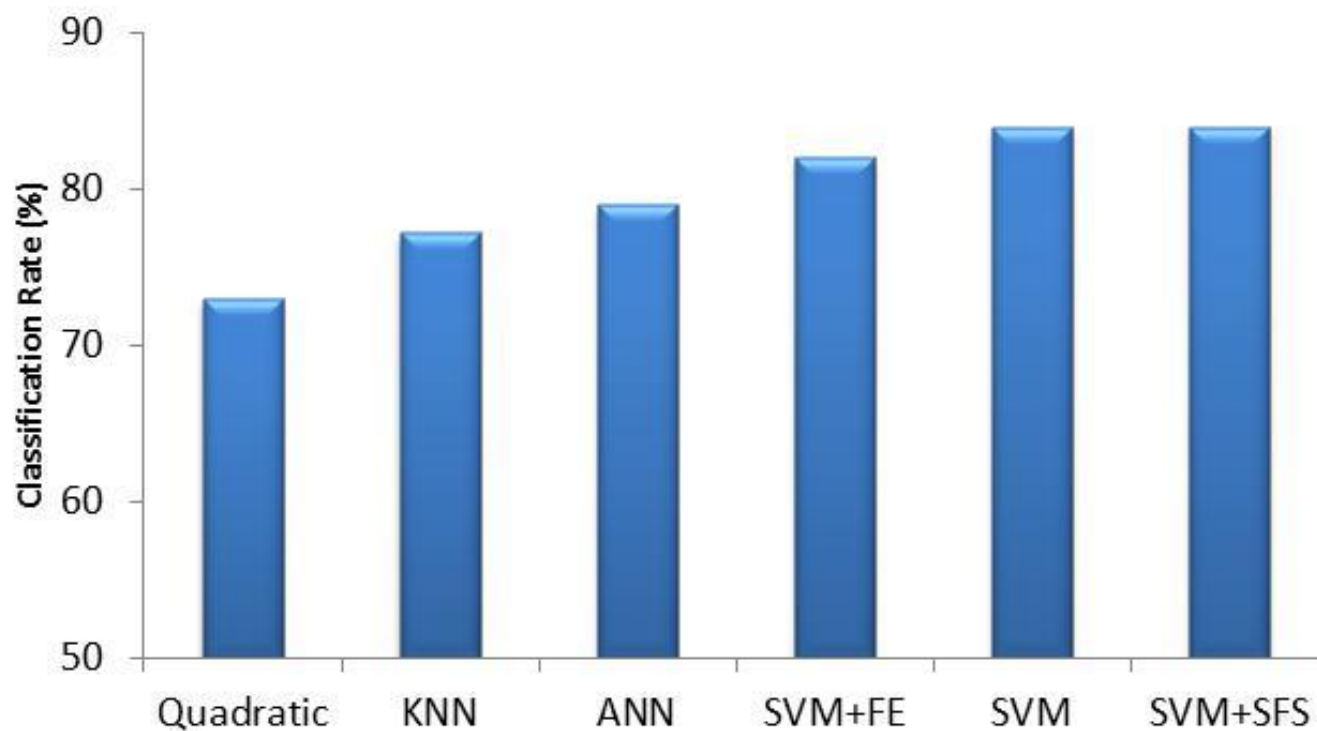
$$x_H^* = \operatorname{argmax}_x - \sum_i P_\theta(y_i|x) \log P_\theta(y_i|x),$$



Результаты: LDA Subspace



Результаты: Passive Learning

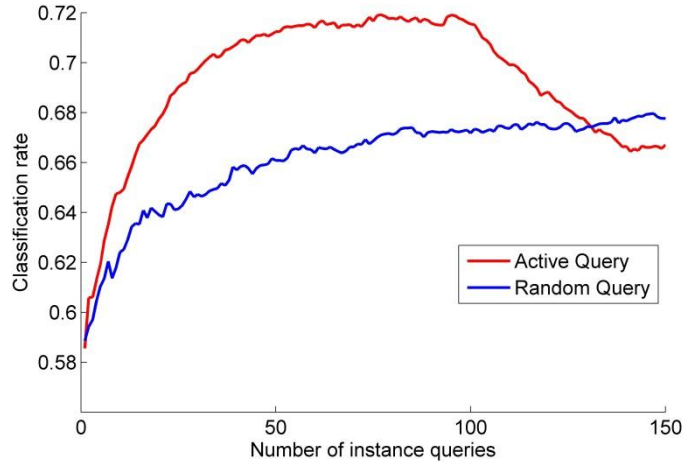


Результаты: Feature Subset Selection

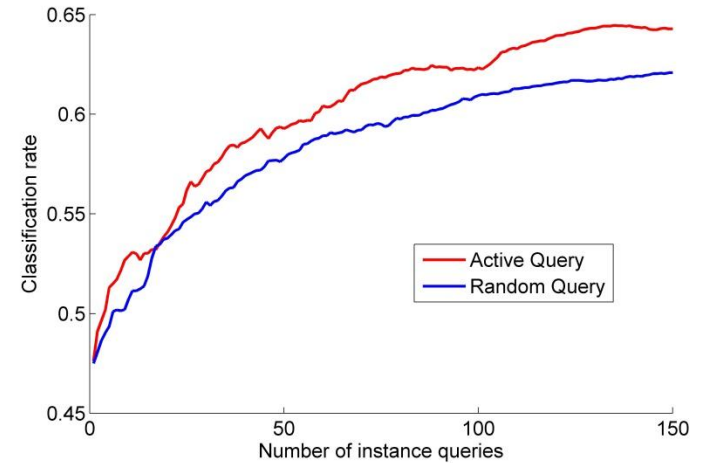
- Sequential Forward Selection (Wrapper)
- Algorithm: SVM
- 10-Fold Cross Validation for each feature subset
- Best Features
 - Variance, 25% Percentile, Frequency-Domain Entropy, Peak Frequency
- Classification Rate of SVM+LDA: 78%
- Classification Rate of SVM+SFS: 84%

Results: Active Learning on Hw2 Data

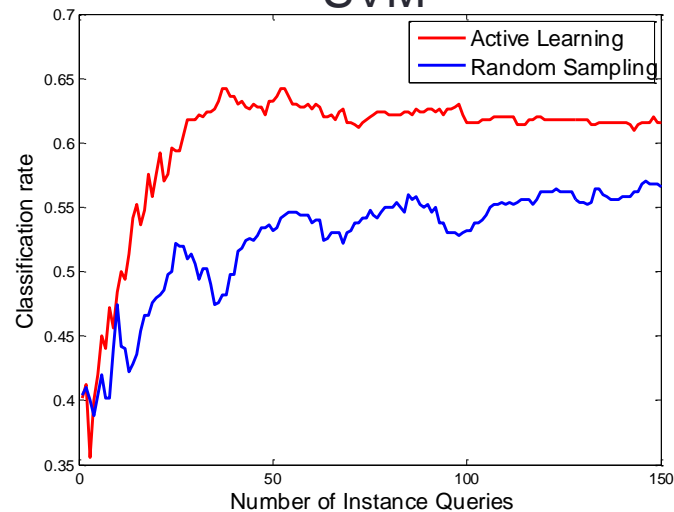
Quadratic



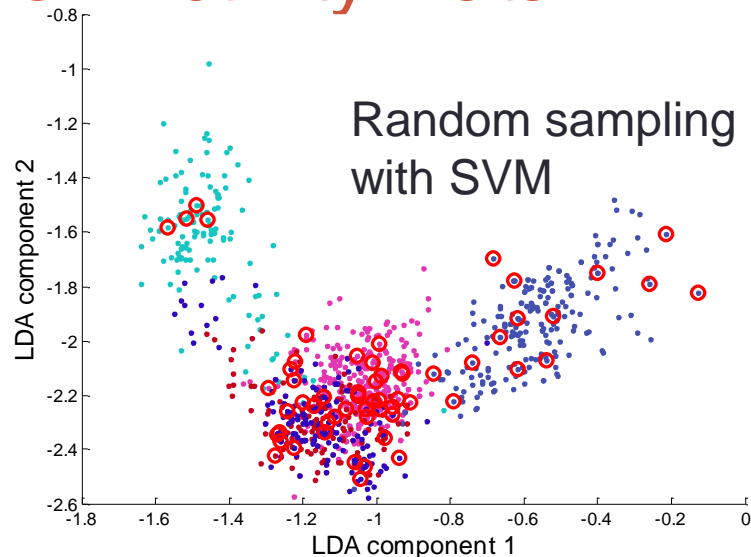
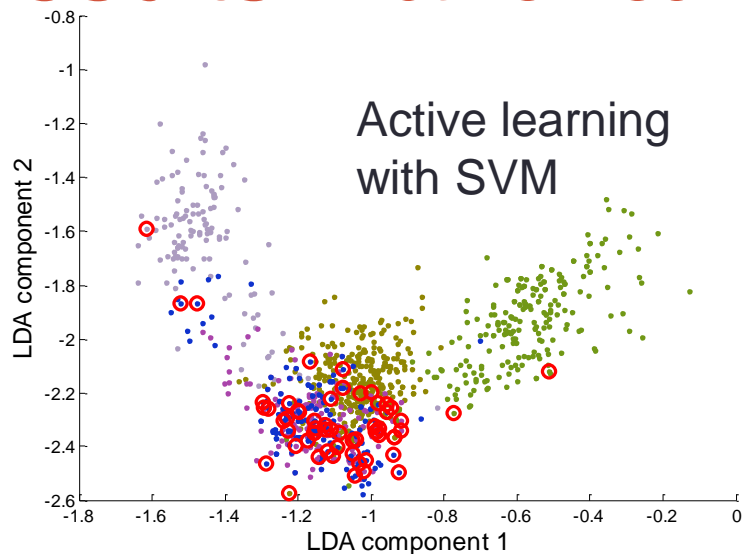
KNN



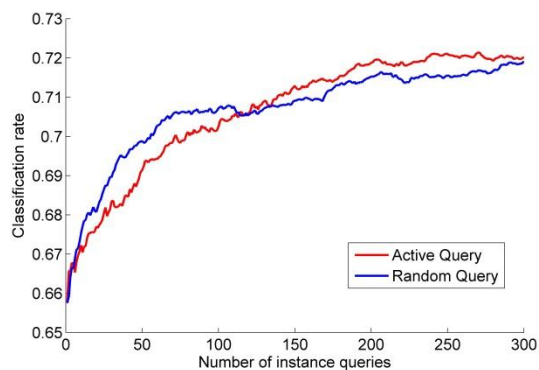
SVM



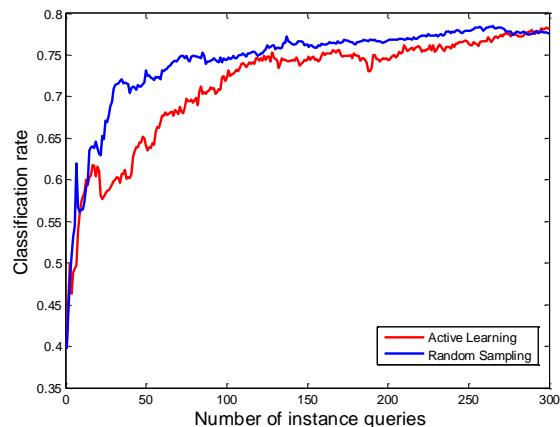
Results: Active Learning on Activity Data



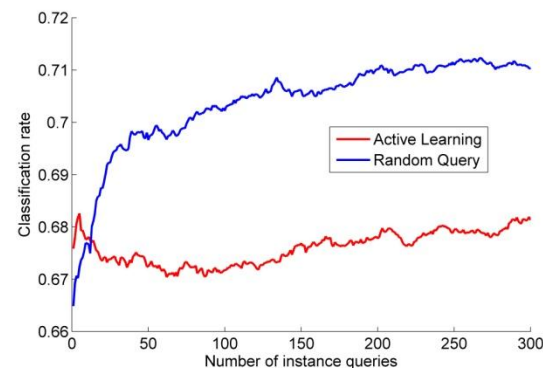
KNN



SVM



Quadratic

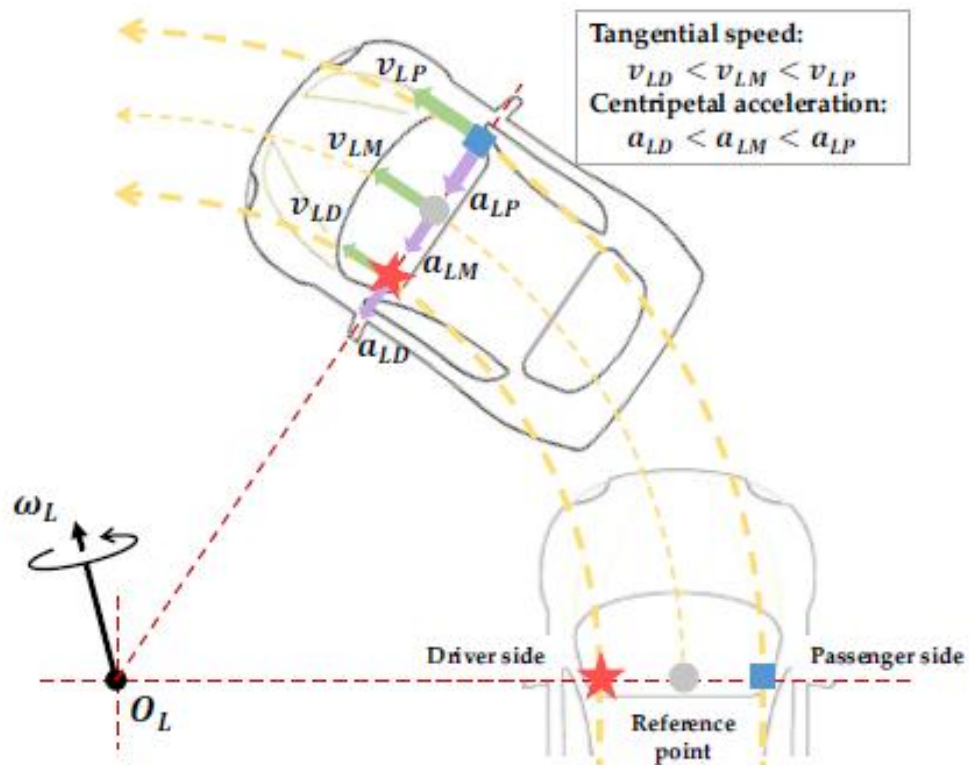


Sensing Vehicle Dynamics for Determining Driver Phone Use

Yan Wang, Jie Yang, Hongbo Liu, Yingying Chen, Marco Gruteser, Richard P. Martin

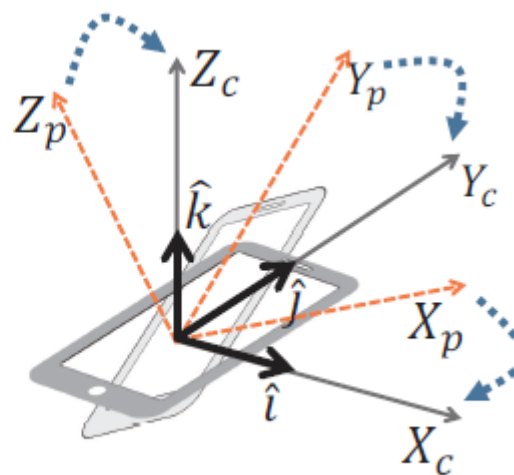
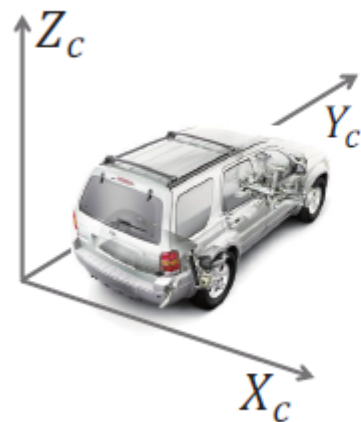
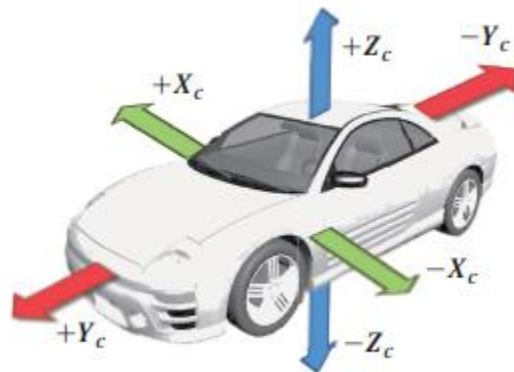
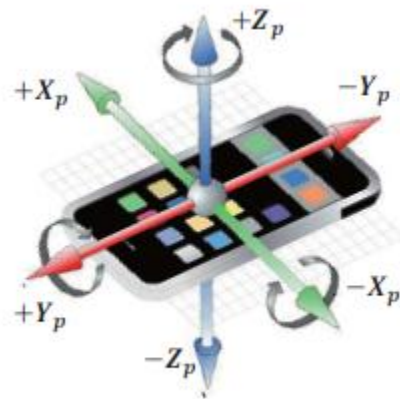


Основная идея



$$a = \omega v = \omega^2 r = \frac{v^2}{r}.$$

Совмещение координат



Совмещение координат

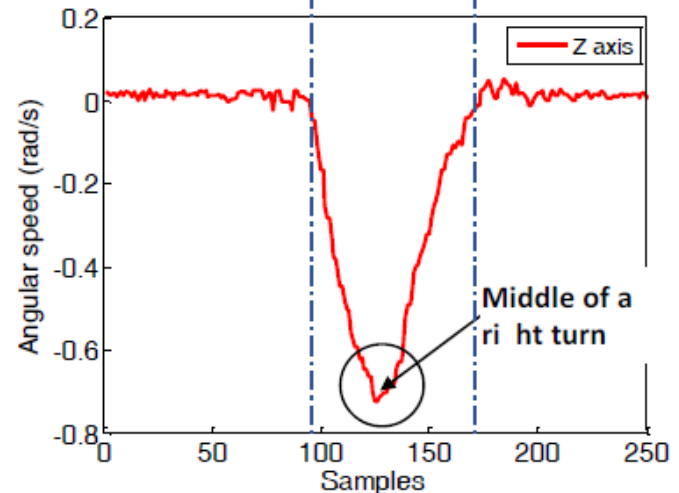
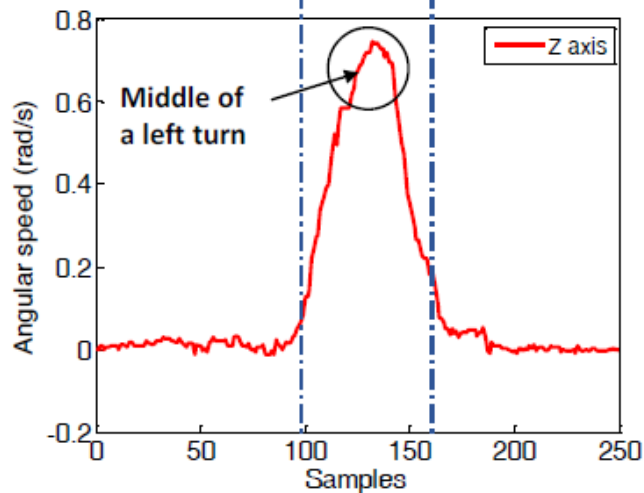
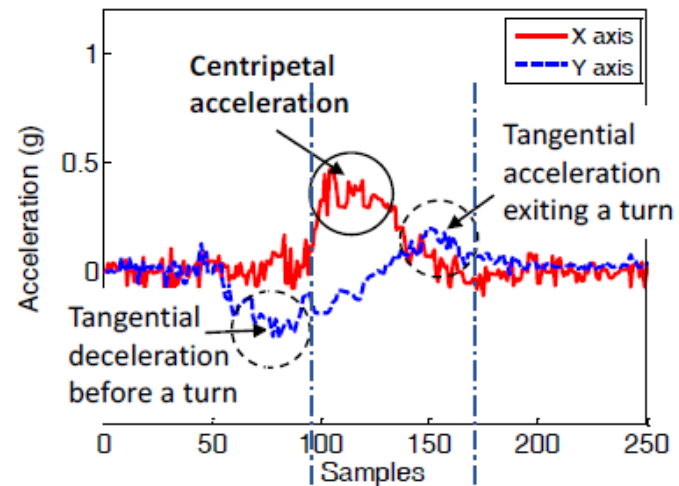
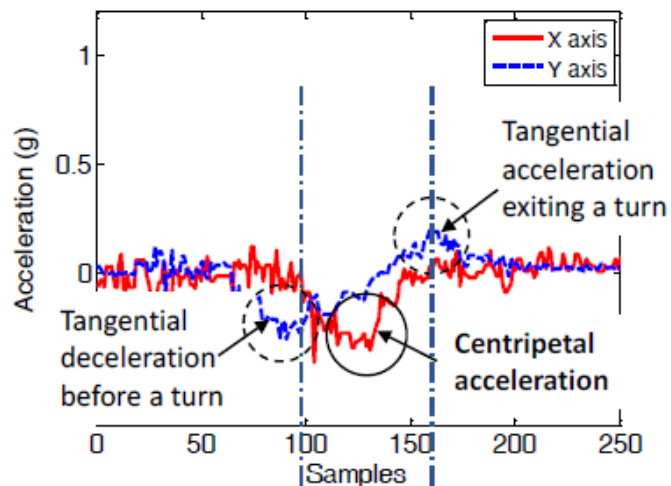
- Координатная система телефона $\{X_p, Y_p, Z_p\}$
- Цель: найти матрицу поворота R от координатной системы телефона к координатной системе автомобиля: $\{X_c, Y_c, Z_c\}$

$$R = \begin{pmatrix} x_i & x_j & x_k \\ y_i & y_j & y_k \\ z_i & z_j & z_k \end{pmatrix}$$

3 шага

- Находим $\hat{k} = [x_k, y_k, z_k]^T$ с помощью фильтра нижних частот.
- Находим $\hat{j} = [x_j, y_j, z_j]^T$ с помощью информации гироскопа.
- Находим $\hat{i} = \hat{j} \times \hat{k} = [x_i, y_i, z_i]^T$

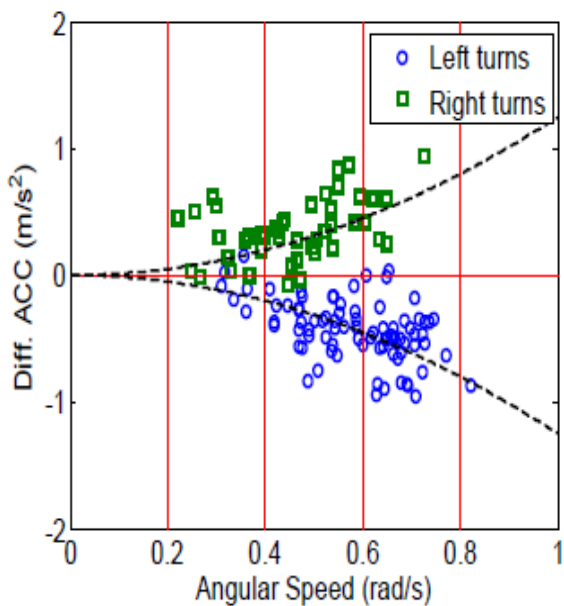
Повороты



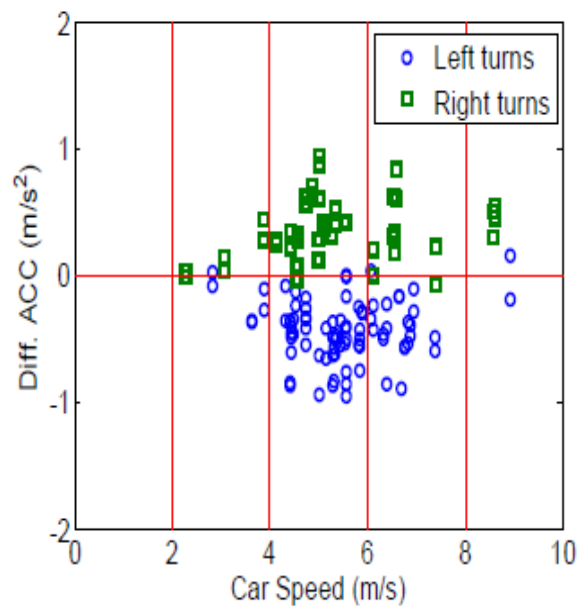
Left turns

Right turns

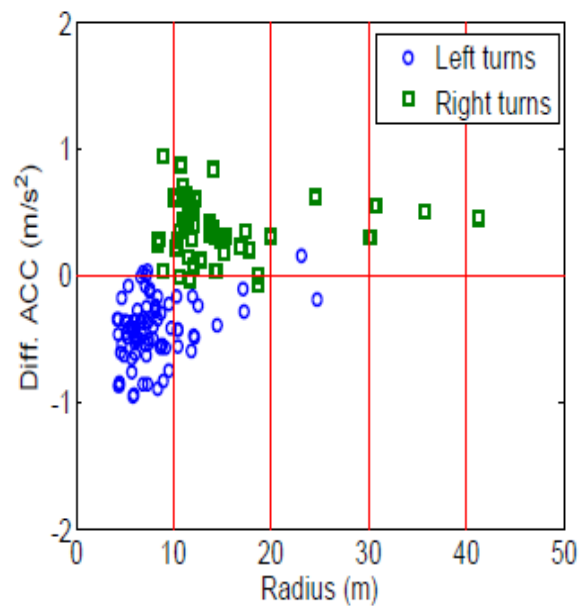
Повороты



(a) Categorized with angular speed

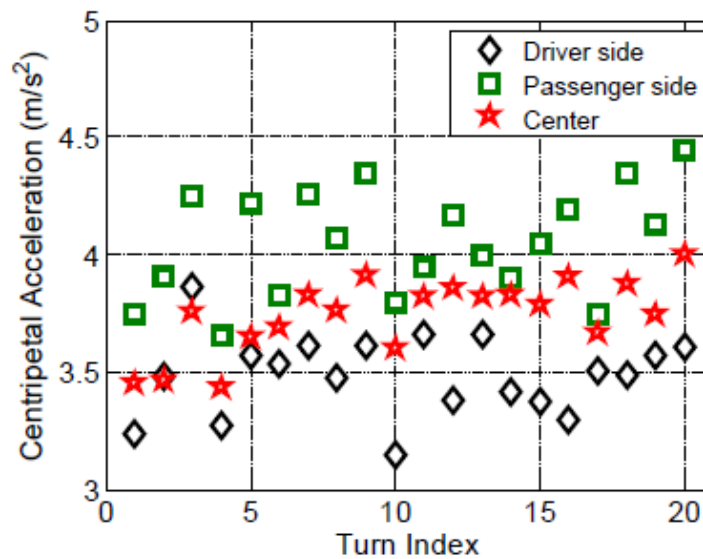


(b) Categorized with car speed (obtained from OBD-II)

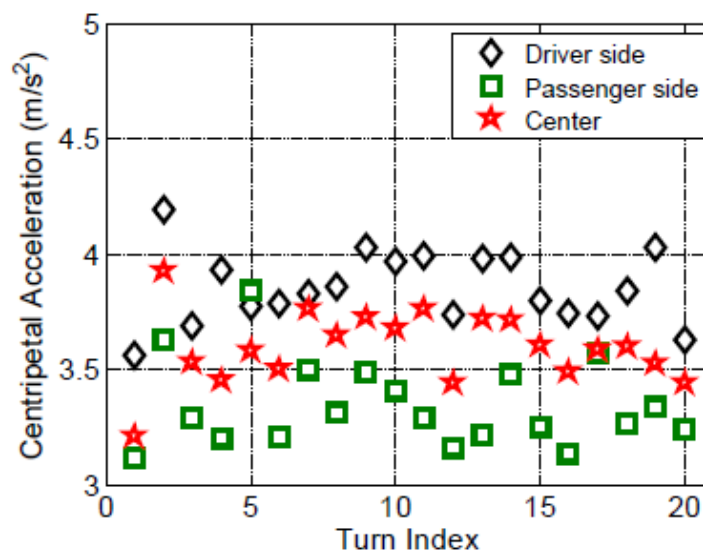


(c) Categorized with turn radius

Повороты

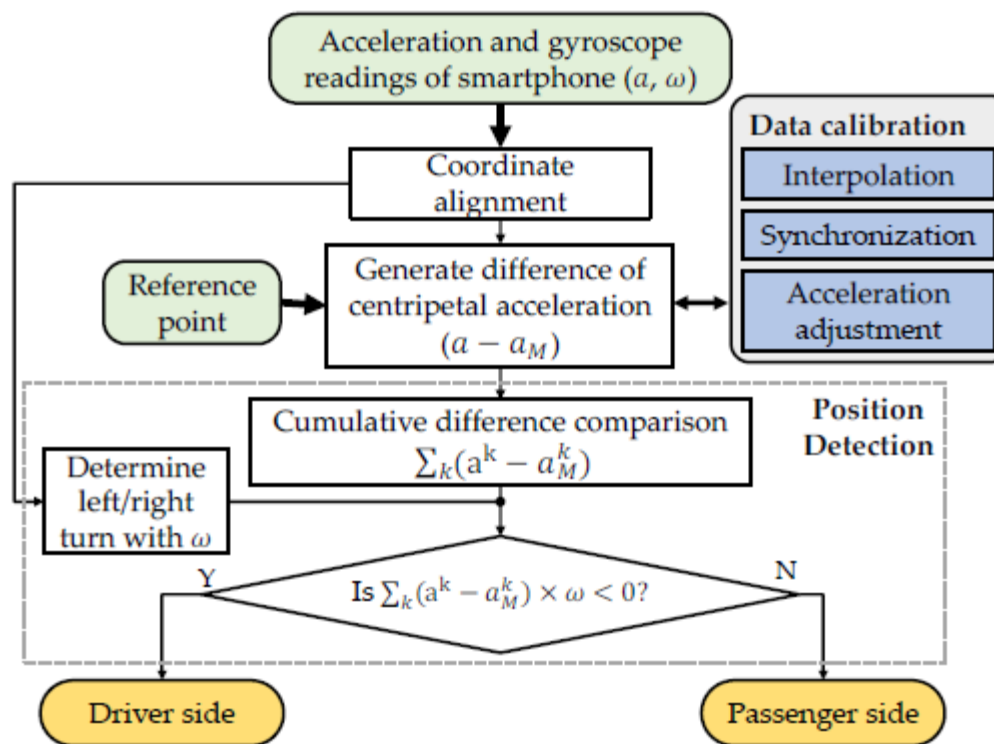


(a) 20 left turns

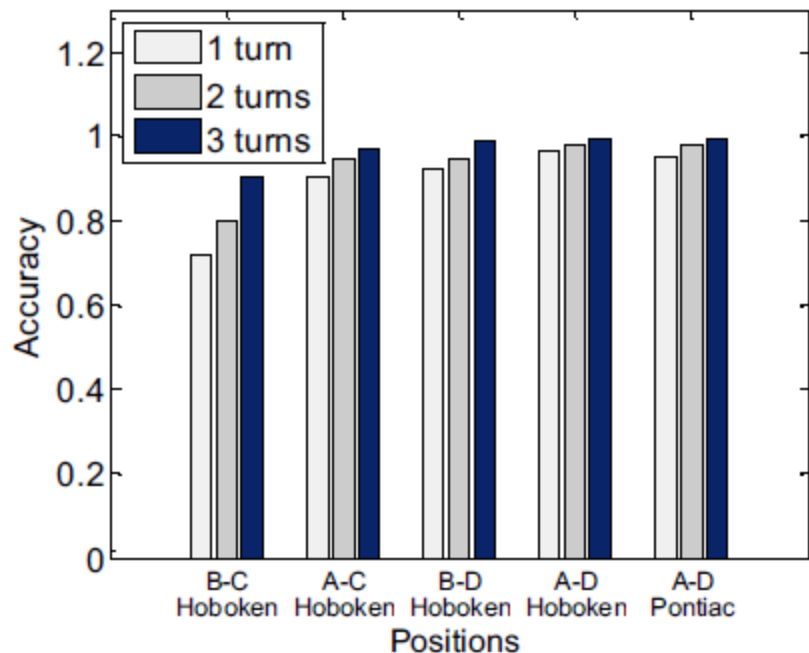


(b) 20 right turns

Общая схема

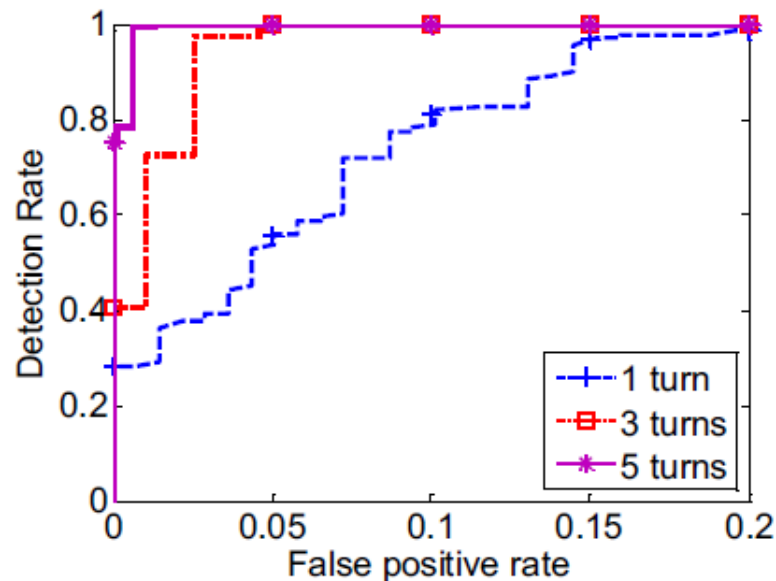


Результаты

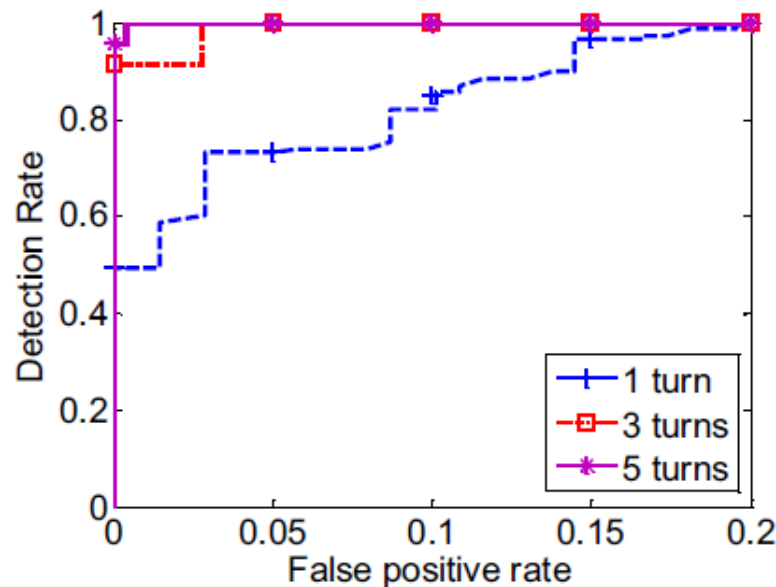


FPR – процент распознавания пассажира, как водителя

DR – процент верных распознаваний водителя



(a) Car A, iPhone4, Hoboken, NJ

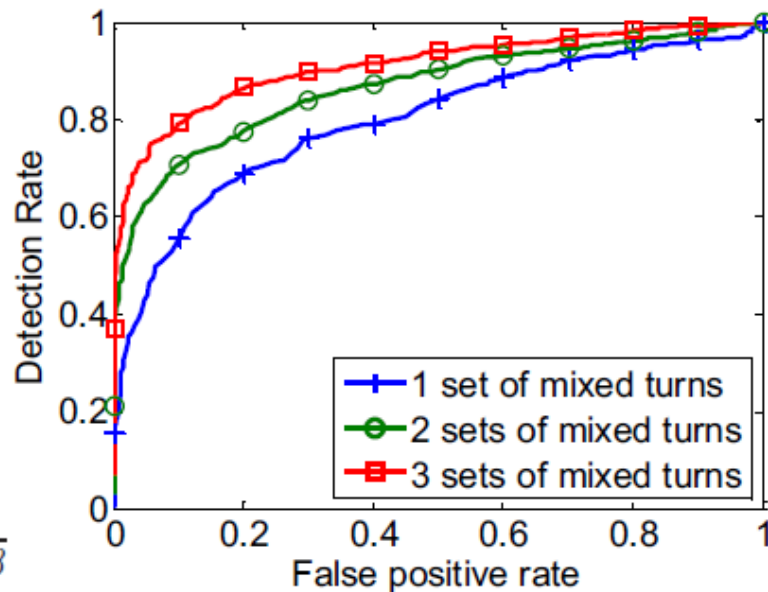


(b) Car B, HTC 3D, Pontiac, MI

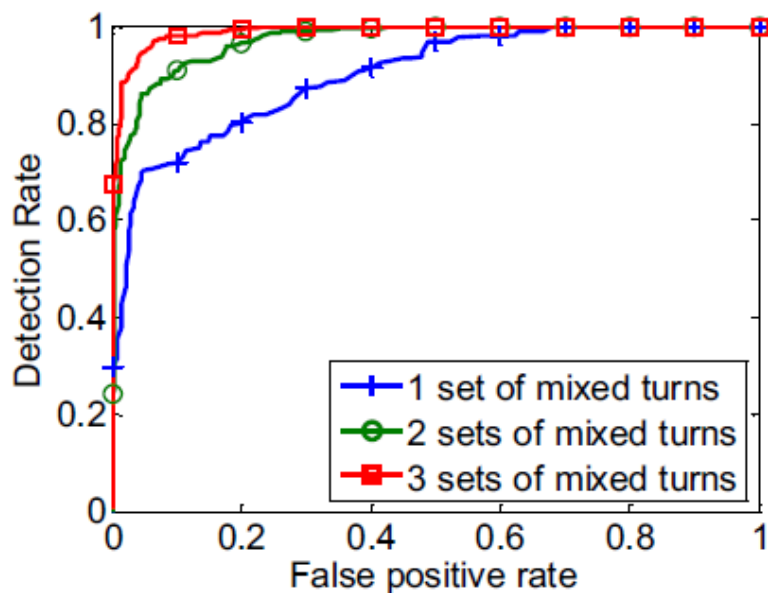
Результаты

$$\begin{aligned} \Delta \hat{a}_r &= \hat{a}_L - \hat{a}_R = \frac{a_L}{a'_{LM}} - \frac{a_R}{a'_{RM}} = \frac{a_L}{a_{LM}\beta} - \frac{a_R}{a_{RM}\beta} \\ &= \frac{1}{\beta} \left(\frac{a_L}{a_{LM}} - \frac{a_R}{a_{RM}} \right). \end{aligned}$$

$$\begin{cases} \hat{a}_L - \hat{a}_R > 0, \mathcal{H}_0 : \text{passenger phone} \\ \hat{a}_L - \hat{a}_R < 0, \mathcal{H}_1 : \text{driver phone.} \end{cases}$$




(a) Without turn selection



(b) With turn selection

Coarse Indoor Localization Based on Activity History

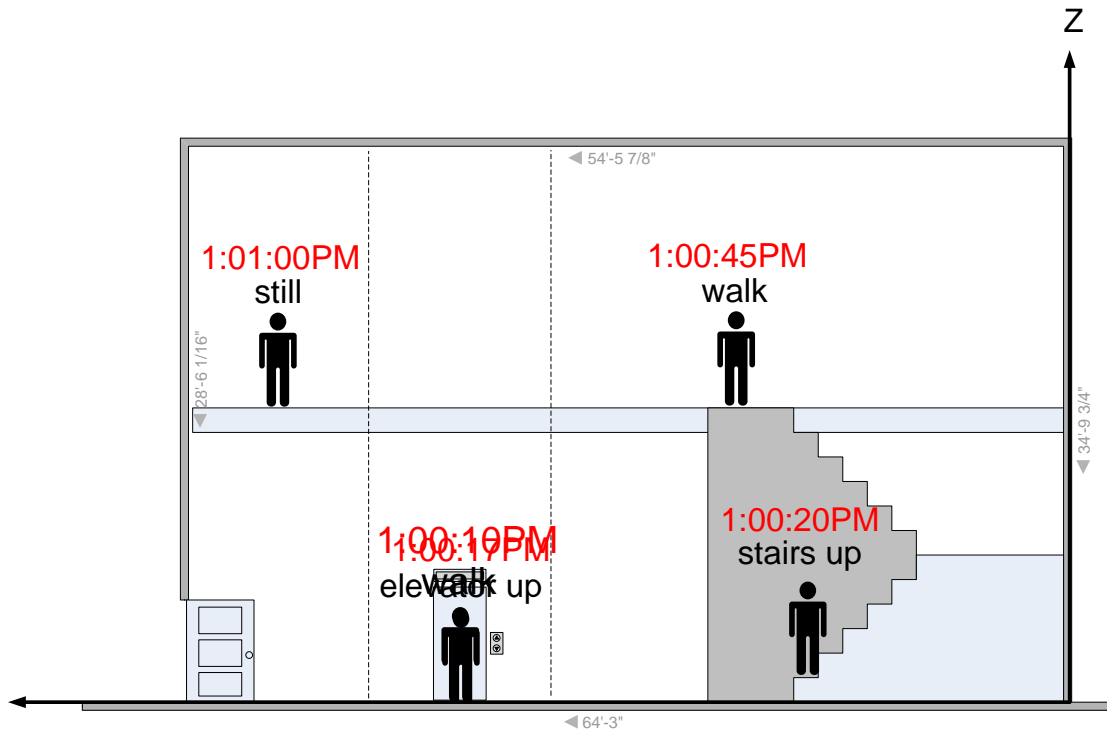
Ken Le, Avinash Parnandi, Pradeep Vaghela, Aalaya Kolli



Have you seen Bob?

I sensed he went up the stairs and walked for a bit





Floor Level Localization

Floor Level Localization

Technology	Equipment	Installation	Configuration	Real-Time
Accelerometer	Low	Low	Low	Yes

- Нужен только акселерометр
- Карта здания не нужна
- Real-time

Activity List for Floor Level Localization

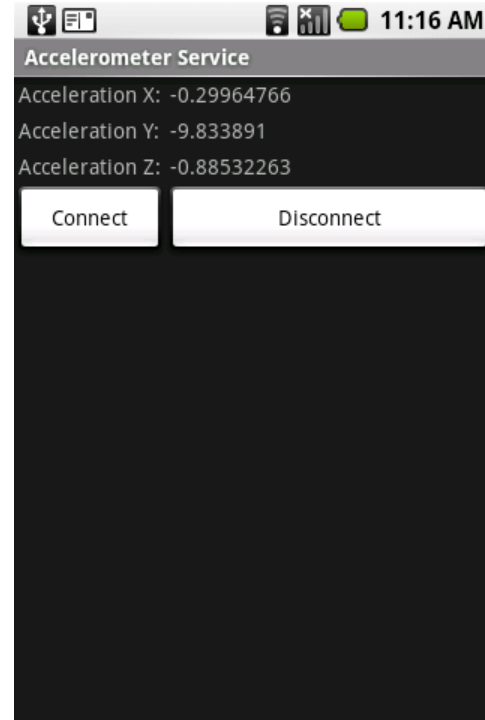
Activity Label	Description
still	The user is standing, sitting, or lying down
walk	The user is walking
stairs_up	The user is going up a staircase
stairs_down	The user is going down a staircase
elevator_up	The user is going up in an elevator
elevator_down	The user is going down in an elevator

Data Collection and Analysis



Hardware

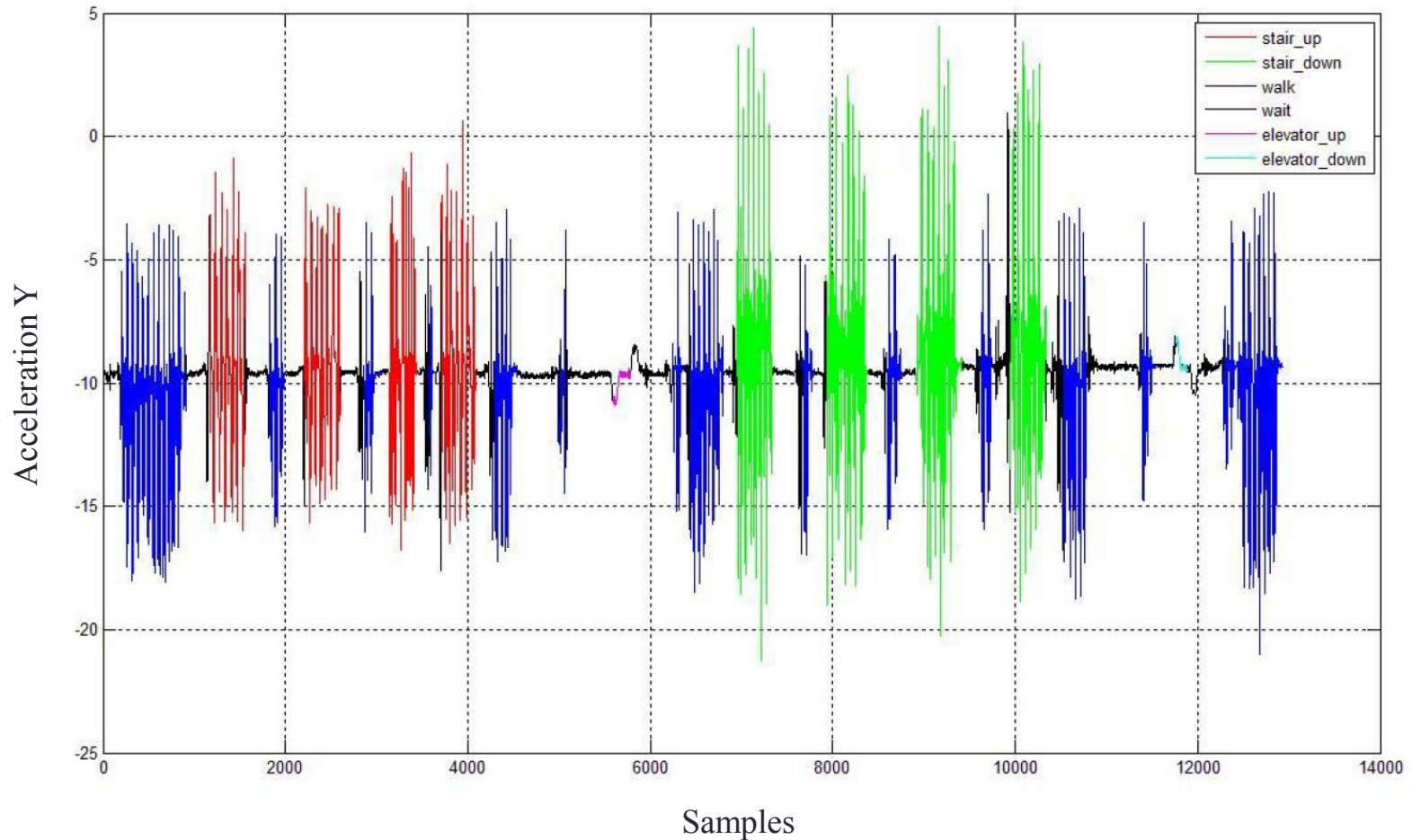
HTC G1 Smartphone
w/ Google Android OS
(embedded Accelerometer)



Software

Accelerometer Data Logger

Data Collection and Analysis

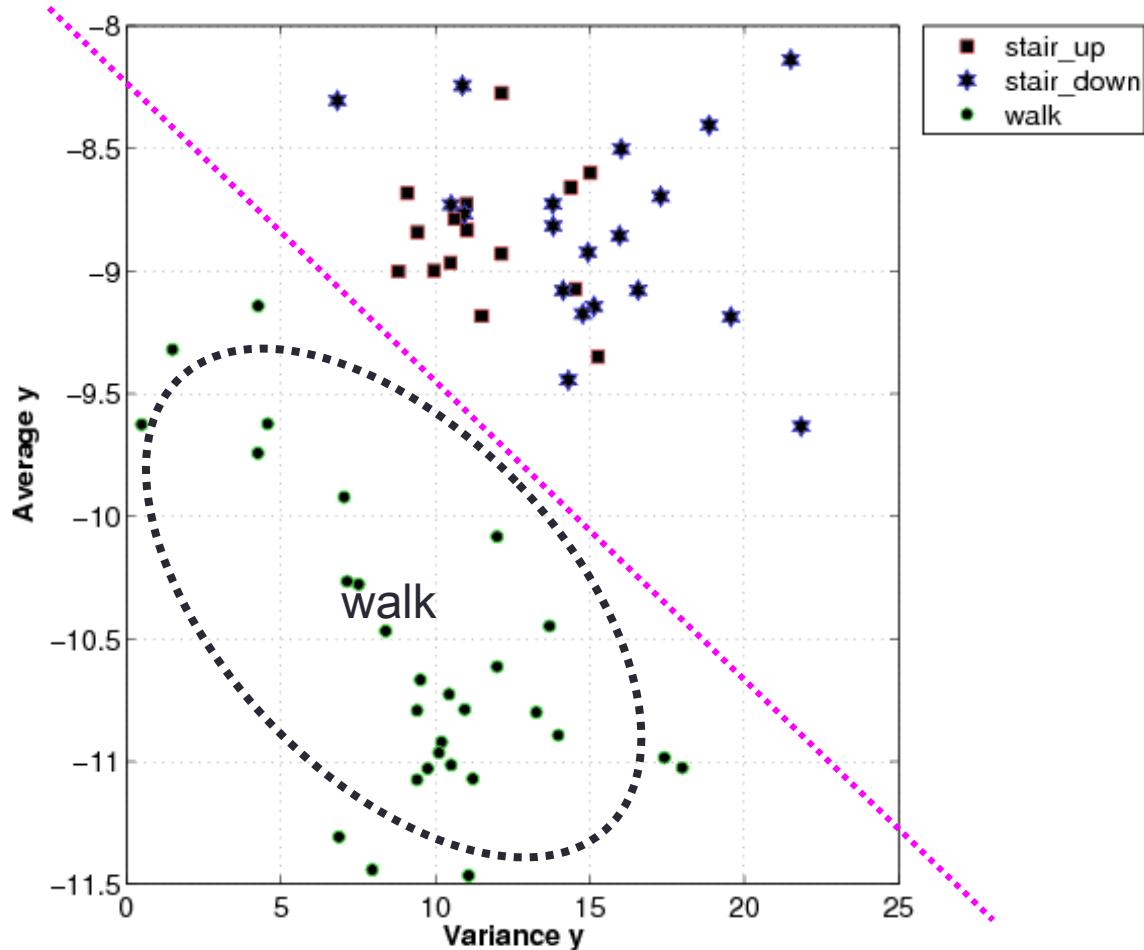


Feature Based Classification

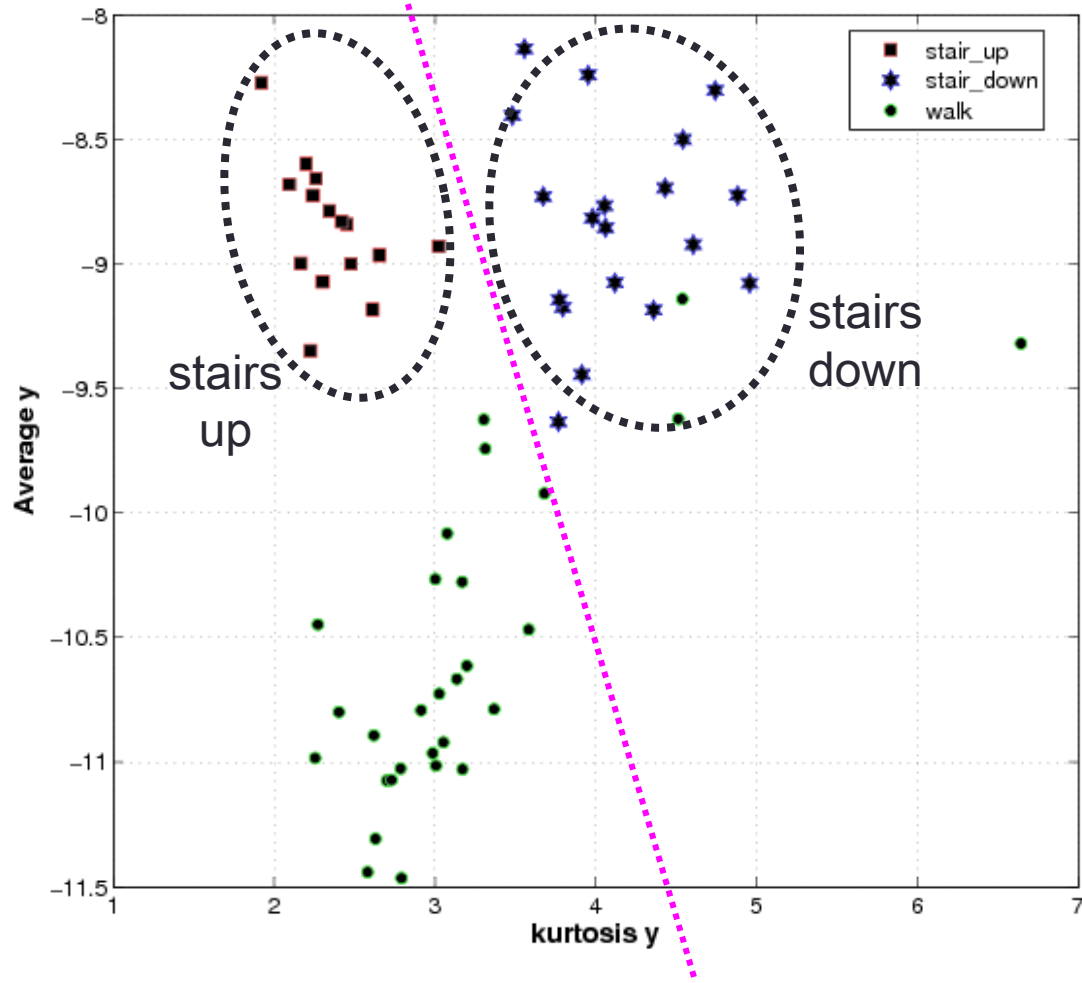
Feature	stair_up vs stair_down	stair_up vs walk	stair_down vs walk
kurtosis y	3.92	31.11	11.32
mean y	44.92	9.55	16.28
energy y	43.00	14.66	19.31
skew y	15.53	49.77	20.12
eccentricity y	45.00	23.11	32.05
variance y	47.00	36.44	21.83
correlation yx	31.30	34.00	49.23
correlation yz	31.30	27.55	52.47
kurtosis x	21.84	48.89	18.58
average x	43.46	50.00	36.79
energy x	33.53	28.89	16.58
skew x	35.38	48.00	26.50
eccentricity x	42.69	52.88	47.13
variance y	45.30	38.66	46.92
correlation xy	31.30	34.00	49.23
correlation xz	41.15	38.66	31.45

Misclassification Rate

Feature Based Classification



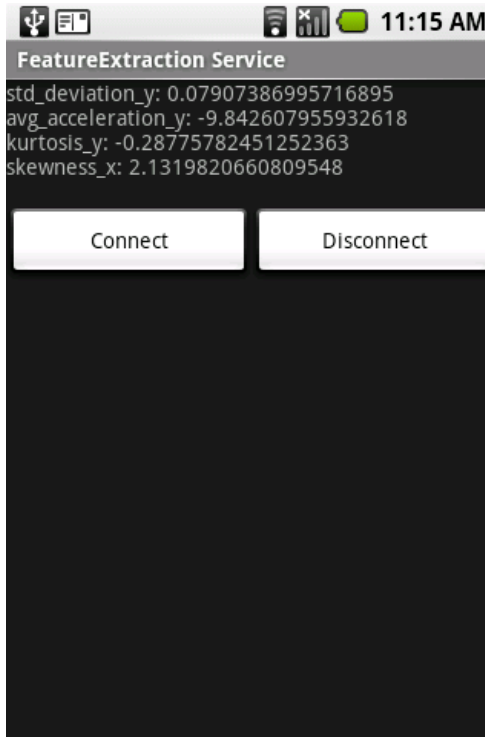
Feature Based Classification



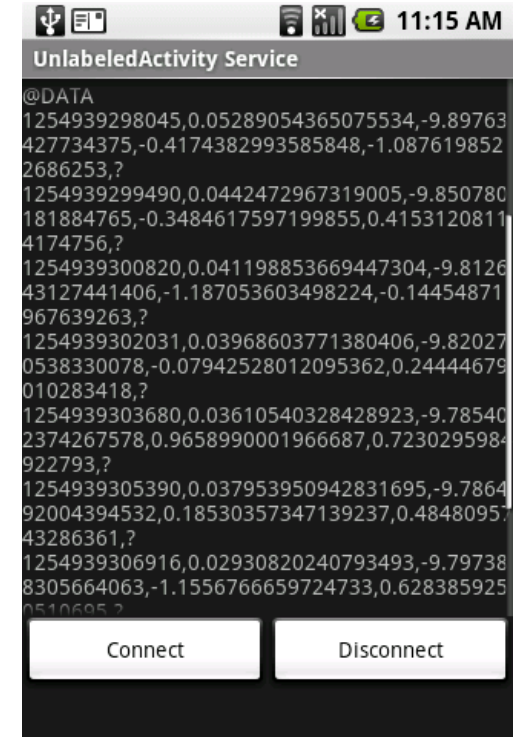
Experimentation



Feature Selector

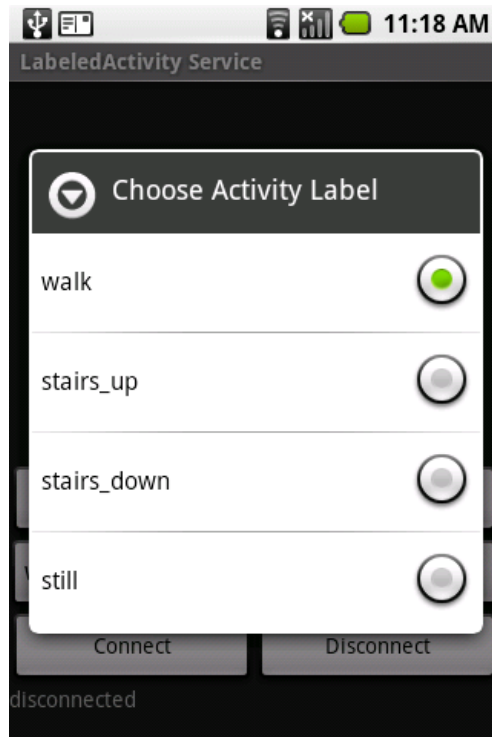


Feature Extractor

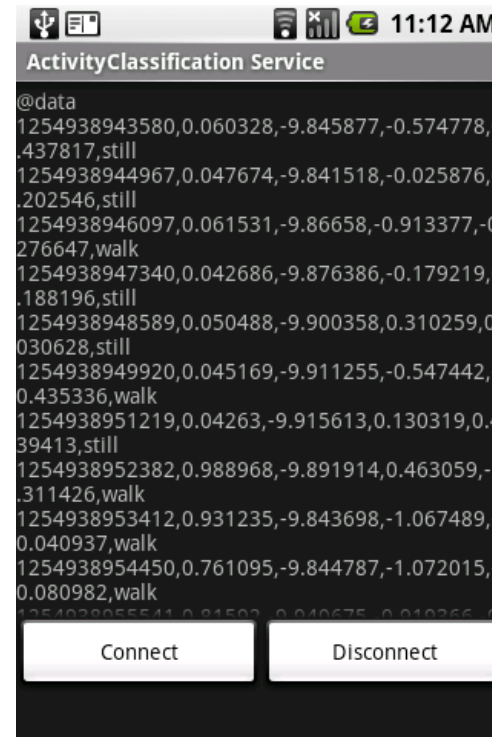


Unlabeled
Activity
Logger

Experimentation

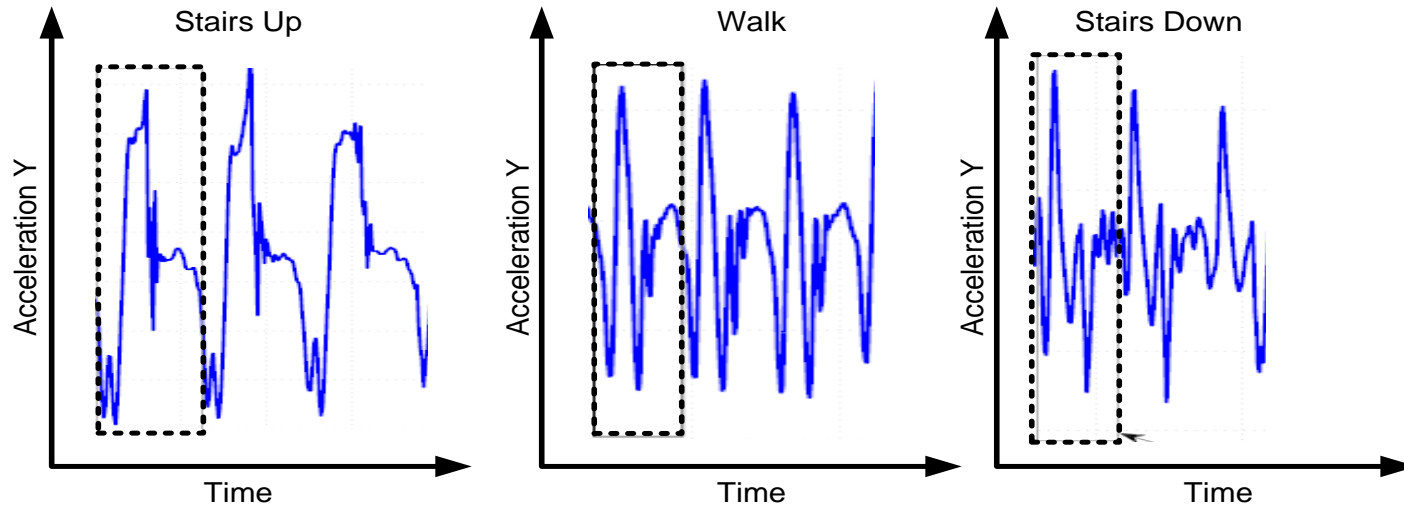


Training

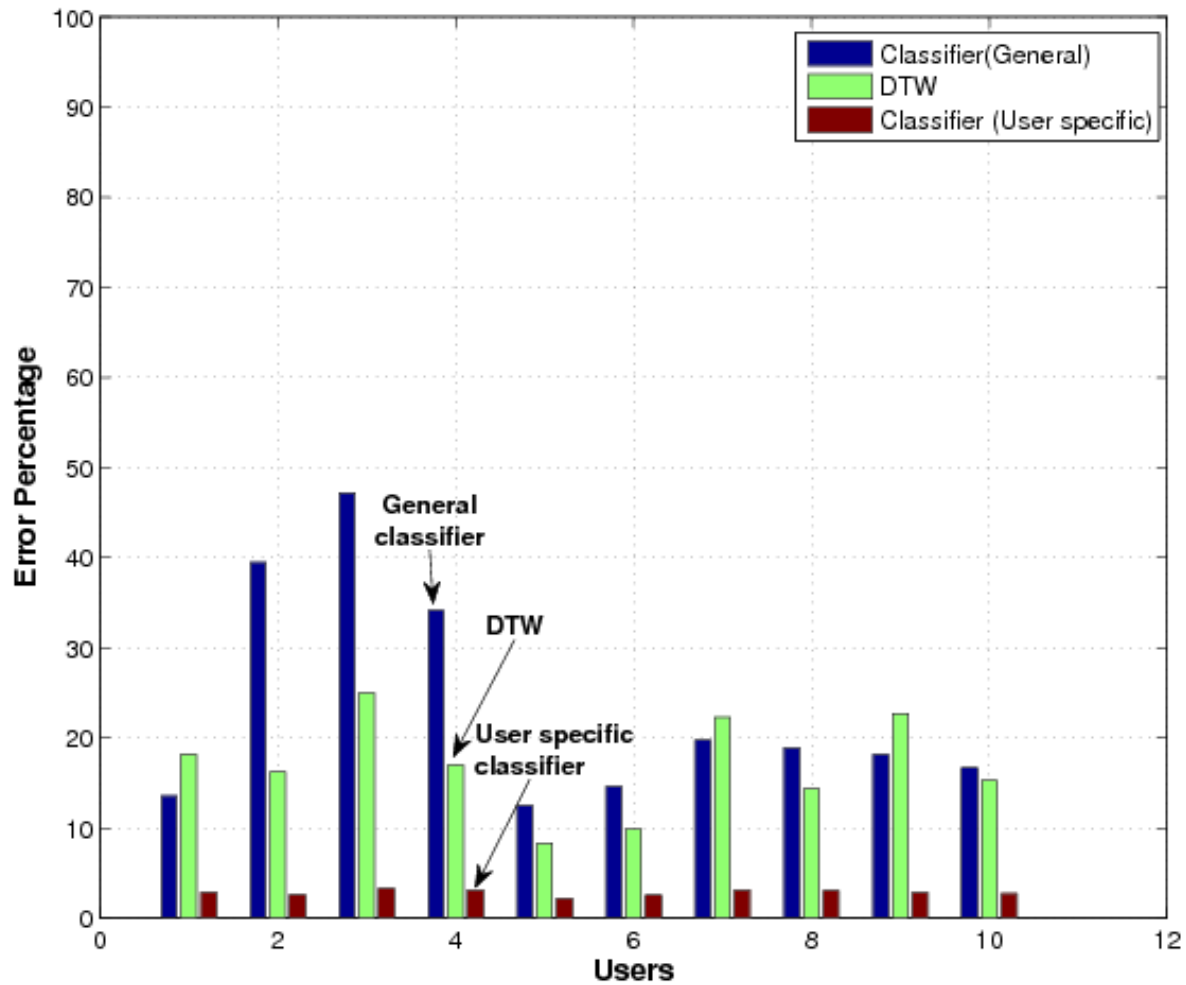


Activity Classification
using Naive Bayes Classifier

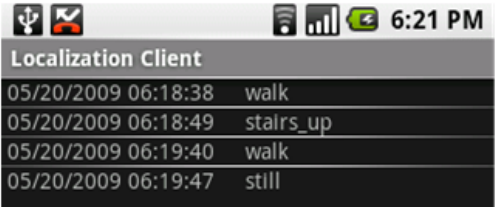
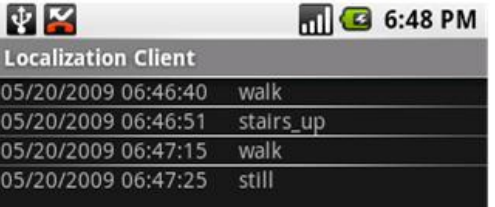
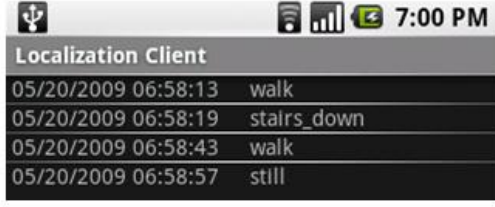
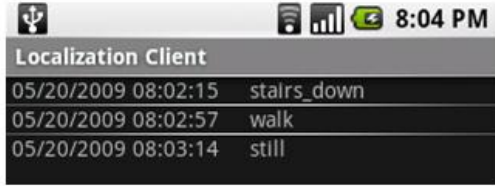
Dynamic Time Warping



Experiment Results

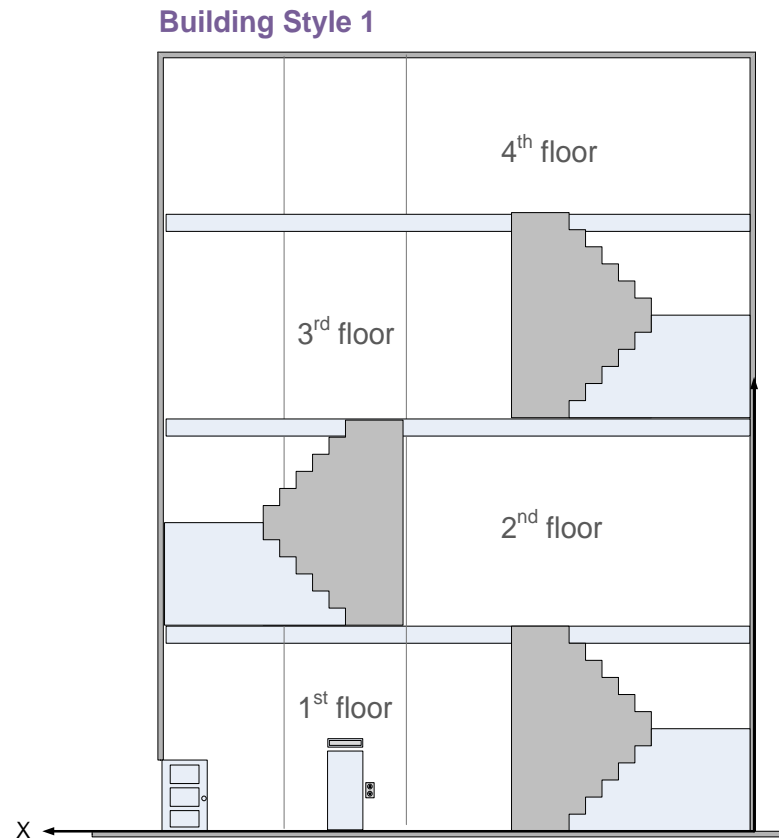


Implementation

Floor Transition	Activity Sequence	Time(s)
1 st to 3 rd	 <p>Localization Client</p> <p>05/20/2009 06:18:38 walk 05/20/2009 06:18:49 stairs_up 05/20/2009 06:19:40 walk 05/20/2009 06:19:47 still</p>	51
1 st to 2 nd	 <p>Localization Client</p> <p>05/20/2009 06:46:40 walk 05/20/2009 06:46:51 stairs_up 05/20/2009 06:47:15 walk 05/20/2009 06:47:25 still</p>	24
2 nd to 1 st	 <p>Localization Client</p> <p>05/20/2009 06:58:13 walk 05/20/2009 06:58:19 stairs_down 05/20/2009 06:58:43 walk 05/20/2009 06:58:57 still</p>	24
3 rd to 1 st	 <p>Localization Client</p> <p>05/20/2009 08:02:15 stairs_down 05/20/2009 08:02:57 walk 05/20/2009 08:03:14 still</p>	42

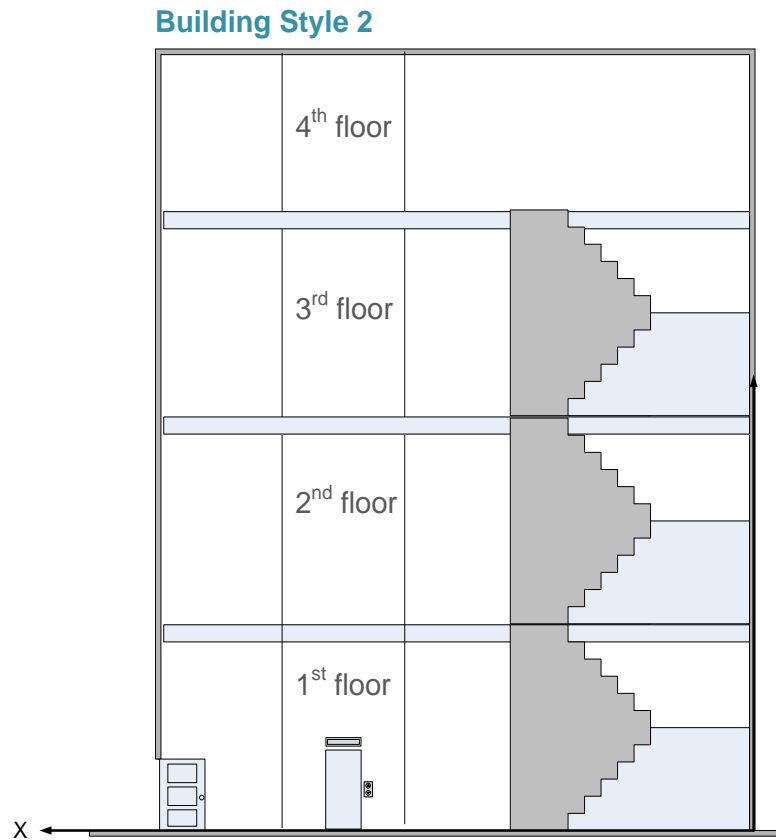
Observations: Floor Localization

- Walk-Stairs-Walk Sequences = One Floor Transition
- $(\text{Elevator Ride Duration}) / (\text{Duration per floor}) = \# \text{ of Floor Transitions}$



Observations: Floor Localization

- Walk-Stairs-Walk Sequences = X Floor Transition
- (***Stairs Duration***)/(***Duration per Floor w/ Stairs***) \approx # of Floor Transitions



Определение местоположения телефона



Данные

- Частота дискретизации 100 Hz
- В обучении:
 - 9 человек
- Данные собирались с помощью разных телефонов (Nokia Lumia 720, Samsung Galaxy, ...)
- 3 основных месторасположения:
 - *Рука*
 - *Карман*
 - *Сумка/рюкзак*

Данные

- Окно – 512 измерений
- Переход к общему ускорению 2 способами:

1. $m_{xyz} = \sqrt{m_x^2 + m_y^2 + m_z^2},$

2. $m_{xyz} = |m_x| + |m_y| + |m_z|$

Признаки

- Для 1 и 2 ускорений:
 - стандартное отклонение,
 - среднее, минимум и максимум
 - 5 перцентилей (10, 25, 50, 75 и 90)
 - сумма и сумма квадратов наблюдений, лежащих выше/ниже перцентилей (5, 10, 25, 75, 90 and 95).
- Для 1 ускорения (сумма квадратов):
 - 32 первые компоненты от FFT
 - применяем WT и от него берем 32 первые компоненты от FFT
- Для 2 ускорения (сумма модулей):
 - среднее значение первой производной
 - количество переходов ускорения телефона через среднее значение ускорения для окна
 - 8 первых компонент от FFT

Результаты

- 50% перекрывающиеся окна
- Всего 4188 окон

Для 9 пользователей:

true/recognition	bag	hand	pocket
bag	0.39	0.28	0.32
hand	0.13	0.69	0.18
pocket	0.18	0.20	0.62

Для 5 пользователей:

true/recognition	bag	hand	pocket
bag	0.629	0.136	0.235
hand	0.047	0.863	0.090
pocket	0.086	0.079	0.834

Спасибо за внимание!

Вопросы?

Литература

- Распознавание на основе сенсорных устройств, закрепленных на телефоне[1, 2, 3,4]
- Использование информации от одной или нескольких камер для распознавания действий[5].
- Совместное использование камер и сенсоров[6]

Reference

- 1) L. Bao and S. S. Intille, "Activity recognition from user-annotated acceleration data," *Pers Comput.*, 2004.
- 2) U. Maurer, A. Rowe, A. Smailagic, and D. Siewiorek, "Location and activity recognition using eWatch: A wearable sensor platform," 2006.
- 3) J. Parkka, M. Ermes, P. Korpipaa, J. Mantyjarvi, J. Peltola, and I. Korhonen, "Activity classification using realistic data from wearable sensors," Jan. 2006.
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- 5) T.B. Moeslund, E. Granum, A survey of computer vision-based human motion capture, 2001
- 6) Y. Tao, H. Hu, H. Zhou, Integration of vision and inertial sensors for 3D arm motion tracking in home-based rehabilitation, 2007