The Winning Solution to AAIA'15 Data Mining Competition: Tagging Firefighters Activities at a Fire Scene

Jan Lasek[1] Marek Gagolewski[2]

[1]Interdisciplinary PhD Studies Program
Institute of Computer Science, Polish Academy of Sciences
janek.lasek@gmail.com

[2]Systems Research Institute, Polish Academy of Sciences
and
Faculty of Mathematics and Information Science, Warsaw University of Technology
gagolews@ibspan.waw.pl

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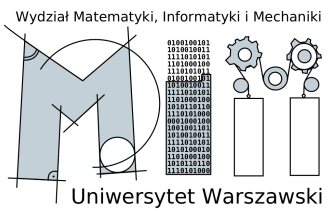
Competition's task

The goal of the competition is to **recognize activities performed by firemen** at an emergency scene.

The competition was organised by Faculty of Mathematics, Informatics and Mechanics of University in Warsaw and Main School of Fire Service in Warsaw.



`https://knowledgepit.fedcsis.org/`

Data

Two datasets are provided – training and test set – of the same size 20K instances:

- each row contains 42 time series of length 400 (i.e., $\approx$ 1.8 sec; sampled every 4-5 milisec.)
- additionally, a set of 42 summary statistics are provided for monitoring a fireman's vital functions
- each instance in the training set is tagged with a pair of labels describing main **posture** and **action** of a fireman
- datasets are of size approximately 2.4 GB

Posture	Action	avg_ecg	.	acc_left_leg_x0	.	gyr_torso_z399
standing	no_action	-0.027	.	-6.98	.	28.49
stooping	manipulating	-0.042	.	-9.40	.	63.84
moving	running	-0.034	.	-36.60	.	-134.26
crawling	searching	-0.040	.	-2.99	.	-7.21
...	...	...	.	...	.	...

Data - sensors

Target attributes

There are two class attributes for dataset: main **posture** and specific **action** performed by a fireman.

	crawl	crouch	move	stand	stoop
ladder_down	0	0	465	0	0
ladder_up	0	0	476	0	0
manipulating	0	1764	331	2356	1898
no_action	0	87	0	491	0
nozzle_usage	0	492	0	443	0
running	0	0	4324	0	0
searching	459	0	0	0	0
sig_hose_pb	0	0	0	98	0
sig_wat_first	0	0	41	496	0
sig_wat_main	0	46	0	405	0
sig_wat_stop	0	0	0	277	0
stairs_down	0	0	644	0	0
stairs_up	0	0	1157	0	0
striking	0	0	0	1022	0
throwing_hose	0	0	0	234	930
walking	0	0	1064	0	0

Sample plot of data

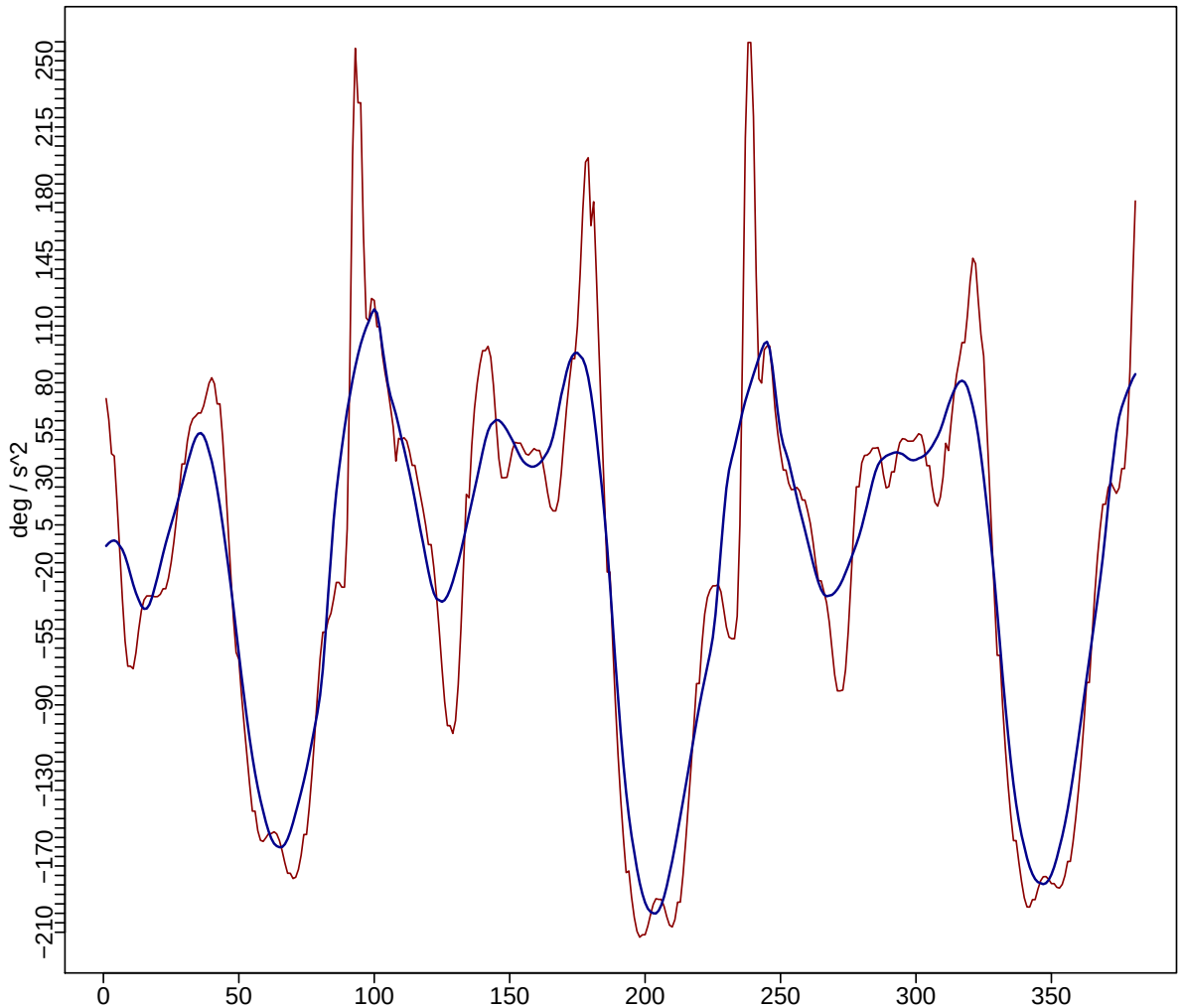


Figure 1 : Plot of raw series (red) and MA filtered (blue) for pair of labels (moving, running) of gyroscope recordings at left hand along x-axis.

Competition evaluation metric – balanced accuracy

Classification accuracy (precision) for a given label:

$$\mathrm{acc}(l_i) = \frac{|\{j : I(x_j) = l_i \wedge p(x_j) = l_i\}|}{|\{j : I(x_j) = l_i\}|}$$

Balanced accuracy score for class C with L labels:

$$\mathrm{BAC}(C) = \frac{1}{L}\sum_{i=1}^{L} \mathrm{acc}(l_i)$$

Evaluation metric is the weighted average of balanced accuracy scores for *posture* and *action* classes:

$$\mathrm{EvaluationMetric} = \frac{1}{3}\mathrm{BAC}(\texttt{posture}) + \frac{2}{3}\mathrm{BAC}(\texttt{action}).$$

During the competition the solutions were evaluated against 10% of test data. Final evaluation was done using the other 90% of data.

Our approach

There are a couple of issues to address:

- How to deal with a classifier in a problem with two (dependent) class attributes?
- What to do with the time series data?
- How to tailor a model to a given evaluation metric – balanced accuracy – given an imbalanced labels distribution within each class?
- How to evaluate model locally?
- Finally, which classifier to use?

Two–class classification task

To tackle the problem of two (dependent) classes in our solution we decided to make predictions in a stepwise model: first predict **posture** and then **action** given posture.

$$\mathbb{P}(posture,\ action) = \mathbb{P}(action \mid posture) \cdot \mathbb{P}(posture)$$

Some other approaches were also tested:

- two independent classifiers
- one–vs–all setup
- labels concatenation

$$posture + action = posture\_action$$

Feature extraction - main part of the solution

We constantly added new features to the training data.

- Basic summary stats: quantiles (**!**), mean, sd, skewness, kurthosis
- some transformations of features: amplitude, "derivative", max(abs(·)) to median ratio
- quantiles, sd of Fourier–transformed data and periodogram of series, first 5 Fourier coefficients
- correlations (**!**)
- We also did some experiments with peaks identification (i.e., the number of sub–chunks of a series where the observations exceeds mean by one or two sd)
- counts how many times a series crosses 0 and its mean

Overall, almost **5000** features were extracted. The dataset size compressed to 1.4 GB (for both training and test set).

Moreover, MA filter for raw series was applied to average them in a window of 20 observation (roughly over 0.1 sec).

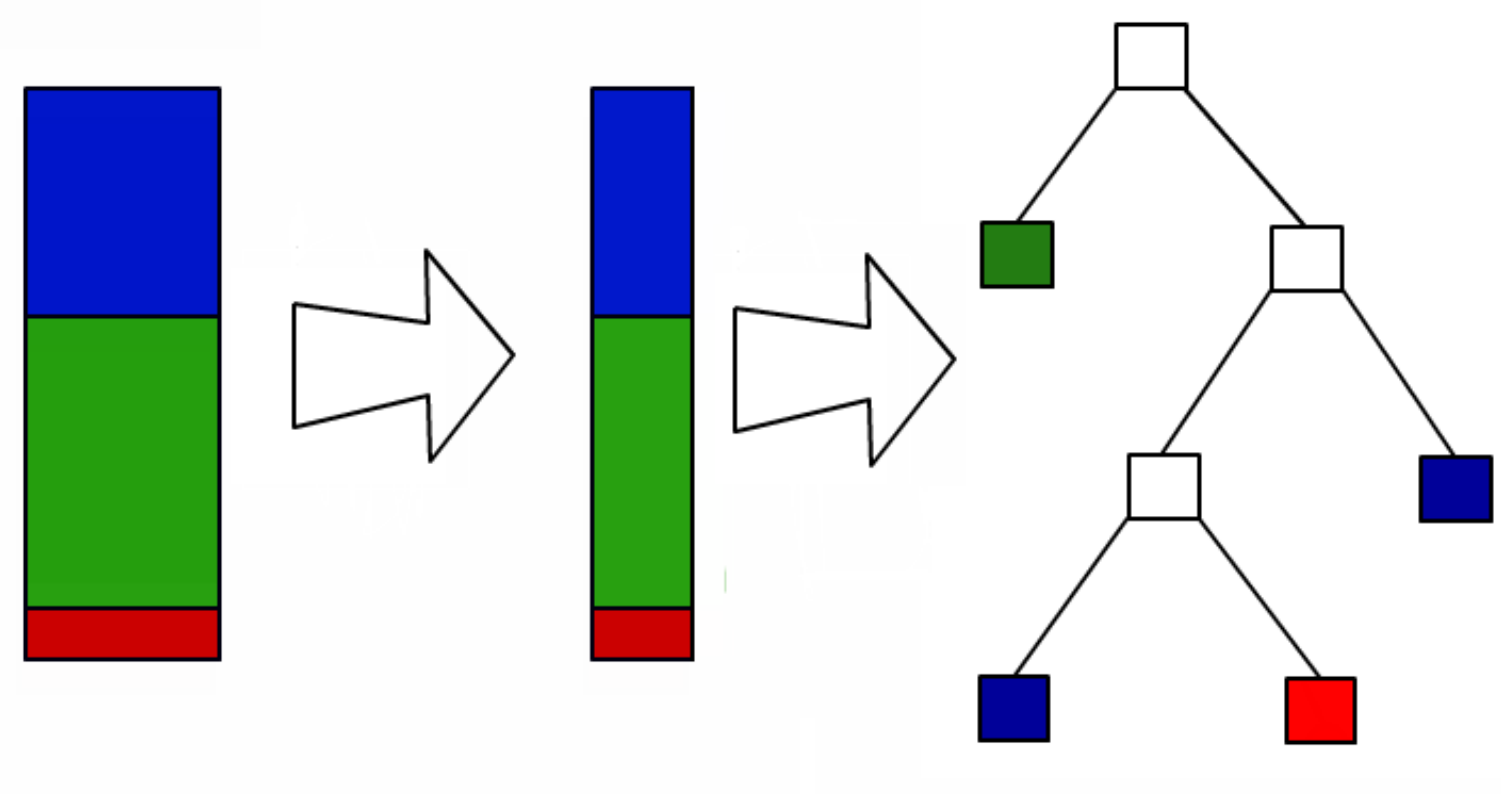
Classifier

To classify both firefighter posture and action we used **Random Forest** model (Breiman, 2001).

- Random Forest is an **ensemble** of decision trees
- The model's prediction are derived by majority voting between weak learners
- This only works if the votes are (approximately) uncorrelated - this is achieved by subsampling both the instances as well as features in the training data
- The model needs to be tailored to evaluation metric proposed in the contest

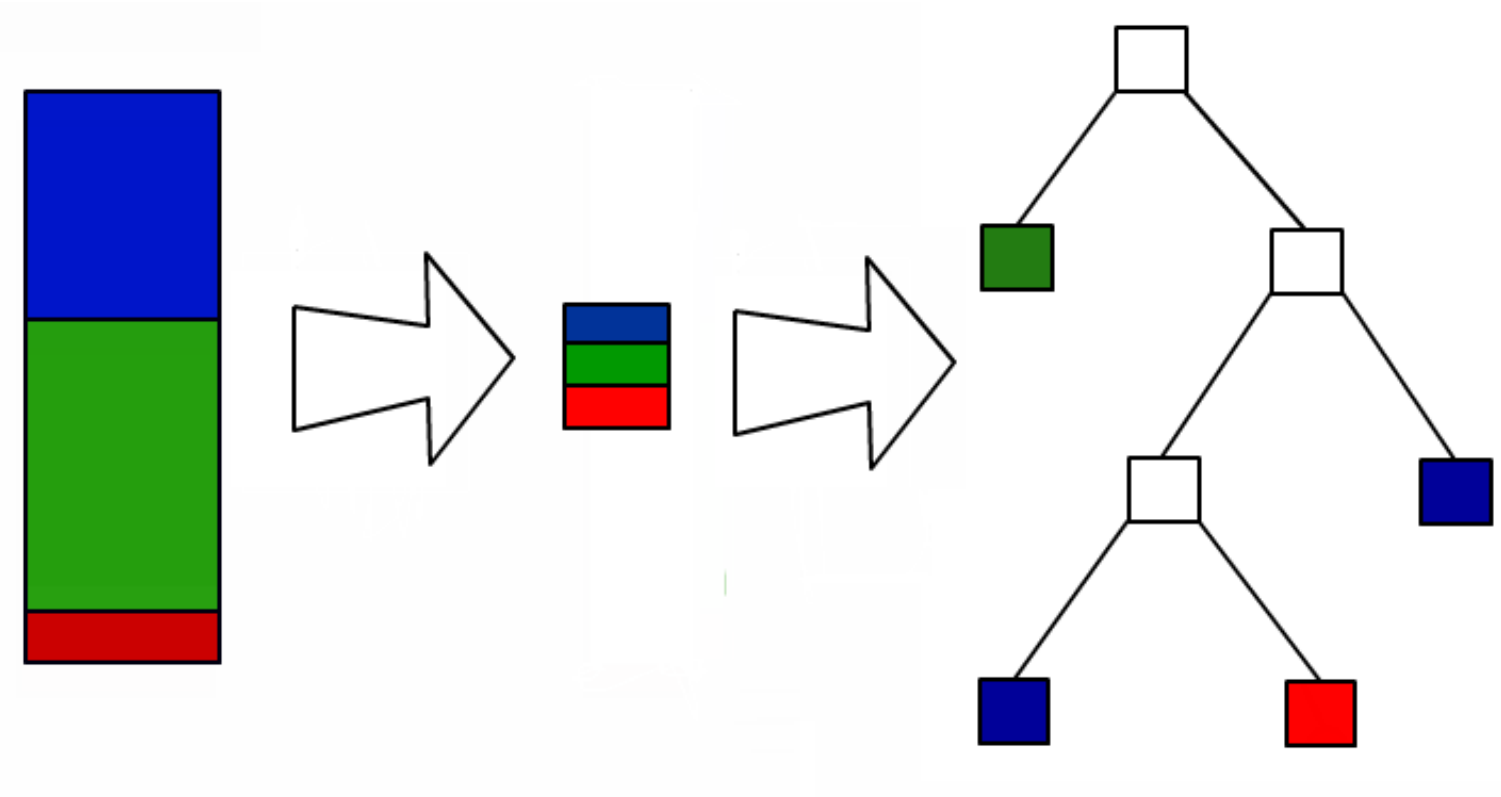
Classifier – Random Forest: usual setup

700 $\times$



Classifier – Random Forest: balanced

700 $\times$



Model optimization

In order to compete you should be able to evaluate your ideas locally: this posed a real challenge.

- the activities in the training set and the test set are performed by different firemen (firemen's identifiers were not provided)
- local evaluation (by cross–validation/on hold–out test set/out–of–bag error) yielded scores as high as 99% accuracy
- my decisions were predominantly based on the results of preliminary evaluation scores on the leader–board

Predictions of the model (paired)

	crawl	crouch	move	stand	stoop
ladder_down	0	**1**	459	**209**	0
ladder_up	0	**2**	452	**118**	0
manipulating	0	1576	12	1639	2438
no_action	0	71	0	467	**31**
nozzle_usage	0	454	0	1060	0
running	0	**13**	3974	0	**2**
searching	513	**42**	0	0	0
signal_hose_pullback	0	0	0	96	0
signal_water_first	0	**3**	10	580	0
signal_water_main	0	55	0	174	0
stairs_down	0	0	533	0	0
stairs_up	0	0	1442	0	0
striking	0	**13**	**7**	1026	**49**
throwing_hose	0	0	0	196	982
walking	0	**2**	1251	**46**	**2**

Unsolved puzzles a.k.a. future work

The main problems with the proposed solution are (still)

- some contradictory pairs of labels – this problem was only limited by the described chaining method
- there are huge discrepancies between local evaluation scores and leader–board results: 99% v.s. 84% of balanced accuracy scores
- the model still does not generalize between different people – perhaps more generic set of features could help

Conclusions

The competition was a very exciting event!

- Thanks to the Organizers and all other Participants
- The source code for the solution is available at GitHub
  `https://github.com/janekl/AAIA15_Data_Mining_Contest`
- If you are interested in this kind of contests visit one of the competition hosting sites
  1. `https://knowledgepit.fedcsis.org/`
  2. `https://www.kaggle.com/`
  3. `http://www.drivendata.org/`
  4. ...

Thank you!

Source: http://www.dziecionline.pl/maluch/bajki/pali/14.htm