Faculty of Biomedical Engineering
SILESIAN UNIVERSITY OF TECHNOLOGY

MASTER'S THESIS

Development of a classification algorithm for basic and distracting driving activities, based on multimodal signals and (deep) machine learning methods.

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Abstract

Praca magisterska powinna zawieraĂ¦ nastĂŞpujÂące elementy:

- sformuÂłowanie problemu,
- analizĂŞ literatury zwiÂązanej z tematem oraz istniejÂącymi rozwiÂązaniami problemu,
- propozycjĂŞ rozwiÂązania problemu oraz wyczerpujÂący opis przyjĂŞtego rozwiÂązania,

- analizĂŞ wynikĂłw i wnioski koĂ±*cowe*. Sugerowana objĂŞtoÂśĂ¦ [tej] pracy to 60-100 stron.

Praca [magisterska] powinna powstaĂ¦ w oparciu o co najmniej 6 pozycji bibliograficznych kwalifikowanych przez promotora (monografie, artykuÂły w czasopismach naukowych, publikacje w materiaÂłach konferencji

1. Introduction

https://www.researchgate.net/publication/338737352$_{D}eep_{L}earning_{f}or_{S}ensor-based_{H}uman_{A}cti$

Human activity recognition involves three factors: users, time, and sensors. First, activity patternsare person-dependent. Diî€ťerent users may have diverse activity styles. Second, activity conceptsvary over time. The assumption that users remain their activity patterns unchanged in a long timeis impractical. Moreover, novel activities are likely to emerge when in use. Thirdly, diverse sensordevices are opportunistically conî€gured on human bodies or in environments. The compositionand the layouts of sensors dramatically inî€žuence the data stimulated by activities. All the threefactors lead toheterogeneityof the sensory data for activity recognition and need to be mitigatedurgently

https://www.sciencedirect.com/science/article/pii/S2590198219300867

The NHTSA classifies three types of driver distraction: visual distraction, manual distraction, and cognitive distraction. In case of visual distraction, the driver looks away from the roadway to obtain information or to control some device, for example, checking and adjusting a GPS or changing the radio station. Manual distraction occurs when a driver takes a hand off the steering wheel, for example, to eat, drink, or smoke. Lastly, cognitive distraction is defined as the mental workload associated with a task that involves thinking about something other than the driving task (National Highway Traffic Safety Administration, 2010). Each type of distraction can work individually or in conjunction with one or more of the other types of distraction.

In 2012, the NHTSA published a guideline for evaluating visual and manual distraction by measuring eye-glance behavior (NHTSA, 2012). However, this guideline did not consider any method for detecting cognitive distraction. Actually, cognitive distraction is the most difficult type of distraction to address, because it occurs within the driver's brain. This phenomenon, which is sometimes referred to as â€looking but not seeingâ€™ (Rizzo and Hurtig, 1987), is not the same as visual distraction (Angell et al., 2006; EngstrĂ¶m et al., 2005).

Wprowadzenie do zagadnieĂ±*poruszanychwpracywogĂlnym, zwiĂŞzÂymujĂŞciu*[1]*.Osadzeniei*

Automatyczna analiza obrazĂłw (AAO)[2] *jest niezwykle istotnÂą i szybko rozwijajÂącÂą siĂŞ dziedzinÂą nauki. Bez narzĂŞdzi (ang.* tools*) AAO trudno dziÂś sobie wyobraziĂ¦ ksiÂąÂżki o przetwarzaniu obrazĂłw [?] i inne. Jednym z popularniejszych narzĂŞdzi analizy sÂą noÂżyczki.*

Opis ewentualnych znanych sposobĂłw rozwiÂązania problemu wraz z ich ocenÂą najlepiej z wyraÂźnym podziaÂłem na zalety i wady, przy czym najlepiej by z wymie-

[1] Projekt inÂżynierski: ±kilka paragrafĂłw.

[2] Tak wprowadzamy skrĂłty.

nionych wad po czĂŞÂści wynikaÂł cel i przyjĂŞte zaÂłoÂżenia.[3]

NoÂżyczki sÂą czĂŞstym tematem prac badawczych. W [?] nie zostaÂły wymienione Âżadne noÂżyczki. NoÂżyczki, ktĂłre nie zostaÂły wymienione w [?], cechujÂą siĂŞ peÂłnym automatyzmem, niestety relatywnie szybko ulegajÂą stĂŞpieniu.

1.1 Overview of the Area

1.2 The Problem

1.3 The Approach

1.4 Outline of the Thesis

Czasem rozdziaÂł koĂ± $czysiĂŞomĂwieniemzawartoÂcipracy, tÂumaczÂcymcoczytelnikznajdzi$

KaÂżdy rozdziaÂł warto jest rĂłwnieÂż poprzedziĂ¦ krĂłtkim wstĂŞpem.

1.5 Aim of the work

SformuÂłowanie celu pracy. OkreÂślenie koniecznych do realizacji zadaĂ±, $niezbĂŞdnychdoosiÂgni$ $projektowychzewentualnympodziaÂemnazaÂoÂeniaogĂlneiszczegĂÂowe$[4].

*Celem pracy jest **stworzenie automatycznych noÂżyczek tnÂących stopnia trzeciego.** Wymaga to realizacji nastĂŞpujÂących etapĂłw:*

- *wyboru narzĂŞdzi,*
- *opracowania architektury noÂżyczek,*
- *testowania noÂżyczek w warunkach zmiennej wilgotnoÂści.*

[3] ± pĂłÂł strony

[4] KrĂłtkie

2. Review of the Literature

In this chapter, a review of available literature on similar topics will be introduced.

2.1 Evaluating driver cognitive distraction by eye tracking: From simulator to driving

According to National Highway Traffic Safety Administration there can be three types of driver distraction distinguished, namely visual distraction, manual distraction and cognitive distraction. All of them are called secondary tasks and have a great impact on the driver's performance. The authors of the article focused on the analysis of the cognitive distraction of drivers, which is described as the mental workload. Since it is not an activity that involves additional movements, rather a thought process that does not concern the main activity, which is driving, the task is not trivial and requires a good method for data acquisition and processing. The authors proposed a method for simulating involuntary eye movement by combining the vestibuloocular reflex model with the optokinetic response, which is then compared with the observed eye movements. The difference between those values is assumed to be a measure of the level of cognitive distraction. For this purpose, the authors decided to use head and eye tracking, specifically Smart Eye for eye movements and Fastrak alectromagnetic tracker for head movements (in driving simulator room) and EyeSeeCam equipment, which is a head-mounted device for collecting eye and head movement (in natural condition). Nine participants (5 men and 4 women) were asked to drive for 3 minutes first without any distractions followed by the addition of auditory simulations, in both real environment and on a simulator. In the second task, every 3 seconds the drivers heard a number and had to decide whether it matches the previous one. They answered by pressing an appropriate button. In such a task the participants not only had to focus on the provided number but also remember the previous one.

In the preprocessing part, the authors used filtering for saccades, removed blink points and used the Kalman Filter for noise reduction. For parameter identification samples of 10 second in length were taken from the experiment without additional mental workload and such sets were used to simulate eye movements in VOR + OKR models.

The performance was measured by comparing the mean-squared error between a 30s time windows of simulated and real signal. Next, to determine the effect of cognitive distraction on vertical eye movement, which is the direction in which the involuntary eye movement while driving usually happens due to the vibration from the vehicle, the authors performed a t-test analysis.

The results showed that the eye movement was abnormal under cognitive distraction yielding the results of t=-5.25, p=0.00038 on the simulator and t=-5.48, $p < 0.005$ in real life environment.

[1]

2.2 Activity Classification in Independent Living Environment with JINS MEME Eyewear

[2]

The article described in this section utilizes the same equipment, which is to be used in this thesis. Therefore, it is gainful to study its performance in activity detection.

The goal of the article according to the authors is:

- examination of the sensors embedded within JINS MEME glasses as a source of data to be used in the classification of activities of daily living,
- development of a method for calculating information about eye and head movements, in addition to basic characteristics of EOG and motion signals, to be used as attributes in the classification process,
- demonstration of techniques for mitigating the problem of imbalanced classes.

The aim of the work was a classification of various activities described as Activities of daily living (ADLs). They were divided into two categories, namely Basic ADLs (BADLs) and instrumental ADLS (IADLs). The first ones are associated with activities that are necessary in everyday live, whereas the latter describes more complex tasks important for independent living.

In the study, twenty six participants were divided into 7 pairs and the rest stayed as individuals. They were asked to spend two hours at The Smart Condo, which is a smart home environment at the University of Alberta and perform specified activities. Additionally, a video recording of all the procedures was acquired to determine the ground truth of participant activities. The JINS MEME smartglasses were worn by 12 participants.

Bathing Dressing Feeding Grooming Toilet Use Walking

IADLs (Instrumental Activities of Daily Living) Cooking Exercise Housework Typing/Writing Watching TV

The Data acquired from the eyewear was cut into 5.6 s overlapping windows. For the preprocessing part, low pass filter as well as bandpass filter were utilized. The first one allowed for noise reduction, whilst the latter helped to eliminate static signal components.

Additionally, higher order attributes were extracted from the EOG signal - blinks, horizontal and vertical saccades. From accelerometer and gyroscope the head movements about Euler angles were determined. In order to remove signal noise without disturbing the overall form of physical movements, a moving average over a duration of 0.05 s was applied. On top of that, a new attribute that corresponds to the nature of used electrodes was introduced. Since dry electrodes do not adhere to the skin surface, in the EOG signal abnormally large peaks appear in response to facial movements or eyewear adjustments. To minimize the influence of those disturbances, the time of occurrence of these peaks is calculated and presented as a percent of the whole sample's length. In the paper, four different machine-learning classifiers were used. However, before feeding the data into the classifiers, class balancing problem had to be addressed. Due to different nature of activities, their duration varied greatly. To avoid the problem of some classes being more favourable than others, the classes that yielded in less than 50 analysis windows were removed from the dataset. For the other classes a technique called SMOTE (Synthetic Minority Over sampling Technique) was used. Finally, the classification could be performed. The four classifiers were: K Nearest Neighbor PART Random Forest Sequential Minimal Optimization (SMO) The best results were obtained using the Random Forest giving the classification accuracy for the activities, using cross validation, between 87.15% and 100% giving the overall activity equal to 93.03%.

2.3 Towards Reading Trackers in the Wild: Detecting Reading Activities by EOG Glasses and Deep Neural Networks

2.4 EOG-Based Eye Movement Classification and Application on HCI Baseball Game

The paper focuses on the investigation of eye movement tracking using electrooculography signal and its use in human-machine systems. The authors proposed eight directional eye movement classification algorithm based on analysis of saccades, therefore they focus greatly on denoising and processing the EOG signal.

The eight eye movement to be determined in this study are: look-up look-left look-down look-right look-up-and-left look-up-and-right look-down-and-left, look-down-and-right The last four are more complex and are composed of two previous activities combined.

The raw signal was acquired with the use of EOG Mindo device from National Chiao Tung University Brain Research Center. There is a set of four electrodes placed around eyes and a reference electrode on the forehead, which result in two horizontal and two vertical signal readings. The data acquired from the sensors is preamplified and denoised thanks to the use of an instrumentation amplifier controlled by a microcontroller program. Using the moving average, the power line noise is reduced and finally, the digitized signal with a sampling rate of 256 Hz is forwarded to the computer via Bluetooth. Once the buffer is full, the obtained signal is passed to the software and prepared for classification.

According to the authors, one of the most crucial steps in the classification is detection and elimination of blinks, since they are the main source of misclassification. Due to the nature of blinks, which have higher amplitude than saccades, they can be easily distinguished by their amplitude. Therefore, by using a peak detection algorithm, they can be filtered out from the signal.

The same algorithm allows for recognizing the eye movement. By analysing the peak upper and lower threshold value, the classification to one of the eight classes can be performed. When the eyes moves straight in one direction, there only one channel becomes activated, however for the complex movements both channels become activated at the same time.

The effectiveness of the proposed method was examined in three set ups - first, a participants had to follow cues appearing on the screen, second, they were allowed to move their sight independently and third, they repeated the previous experiment on a smaller screen.

The first experiment yielded almost perfect results, providing the correct rate between 94 and 100%. The experiment without cues also produced satisfactory yet less accurate results with the lowest score of 90% for three of the movements. The last test, performed on a small scale device, produced results that were mostly above 90%.

The tests performed on the target activity revealed that the application works with 90% mean accuracy, after performing 5 HCI Baseball Games.

2.5 A Custom EOG-Based HMI Using Neural Network Modeling to Real-Time for the Trajectory Tracking of a Manipulator Robot

The authors of this article focuses on the analysis of human-machine interface (HMI), particularly on human's individual characteristics and the way they affect the performance of HMI systems. To measure that dependency, the

Therefore, in this work the use of a multilayer neural network (MNN) to model the EOG signal as a mathematical function is presented, which is optimized using genetic algorithms, in order to obtain the maximum and minimum amplitude threshold of the EOG signal of each person to calibrate the designed interface.

In this paper, it was considered that the human and individual characteristics affect the execution of the task that the HMI perform; these parameters are highly variable, and it is required to analyze and reduce the effects on the efficiency of the system. It is difficult to determine the level of adaptability or personalization of an HMI; however, calibrating a system looking for it to adapt to the personal parameters of a user has been shown to decrease the learning curve, improving the level of acceptance of inexperienced users. The proposed HMI will be implemented in the future to assist people with severe disabilities, where a manipulator robot will be adapted to a wheelchair, so that the user can control the movements of the robot by means of orientation of the gaze with the ability of taking objects and increasing their autonomy.

2.6

2.7 Od promotora

3. Hardware

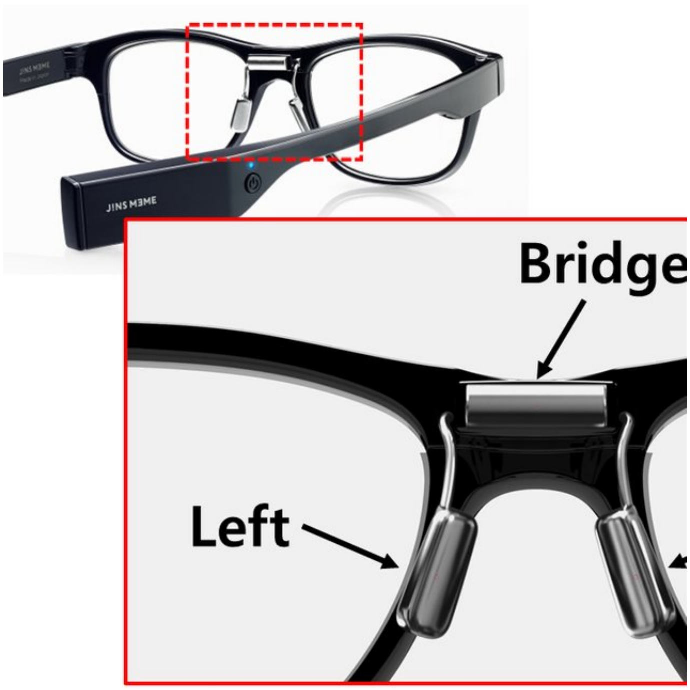
3.1 JINS MEME Smart Glasses

3.2 Driving simulator

4. Data collection

4.1 Scenarios

4.2 Study participants

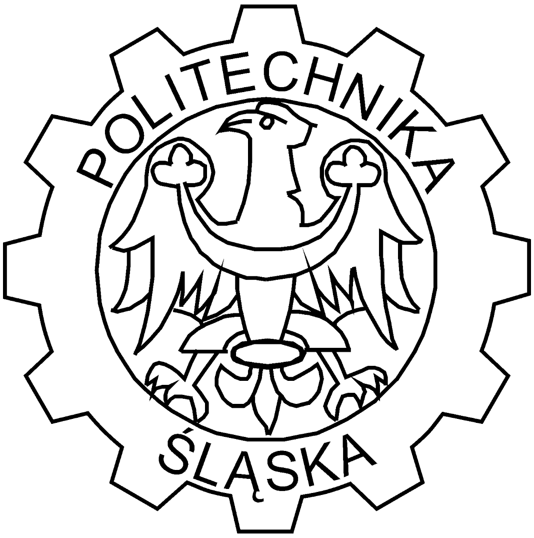


Rys. 4.1: JINS MEME Smart Glasses[1]

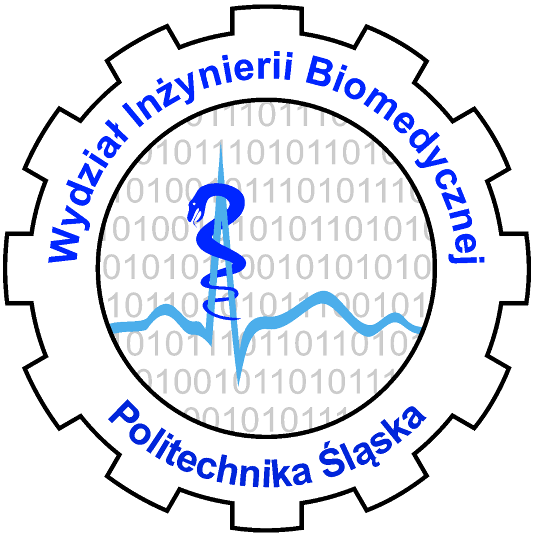
Stworzenie odpornych, automatycznych noÂżyczek tnÂących stopnia trzeciego wymaga opracowania wieloetapowej metodologii. W pierwszej kolejnoÂści rozwaÂżona zostanie odpornoÂśĂ‡ na korozjĂŞ cyfrowÂą. W dalszej czĂŞÂści pracy...

4.3 Problem 1

Stworzone noÂżyczki powinny cechowaĂ‡ siĂŞ duÂżÂą odpornoÂściÂą na korozjĂŞ cyfrowÂą. MoÂżna w tym celu wykorzstaĂ‡ izolacjĂŞ od znakĂłw wodnych (Rys. 4.2) na poziomie warstwy pÂłĂłtna.



(a) Podpis 1



(b) Podpis 2

Rys. 4.2: Podpis caÂłoÂści nawiÂązujÂący do podpisu (a).

5. Preprocessing

CzĂŞÂśĂ¦ konstrukcyjna lub implementacyjna, tÂłumaczÂąca sposĂłb realizacji zadania, omĂłwionÂą w poprzedniej czĂŞÂści opracowania. WyjaÂśnienie wyborĂłw elementĂłw, sprzĂŞtu lub programĂłw. W przypadku programĂłw obiektowych podziaÂł na klasy, pola, metody wraz z uzasadnieniem.

6. Analysis

7. Internal Specification

W trakcie realizacji zadania, w pierwszym kroku, naleÂży odizolowaĂ¦ znaki wodne w warstwie pÂłĂłtna. Wykorzystano w tym celu dostĂŞpnÂą w Âśrodowisku XYZ funkcje Z. Parametry do funkcji okreÂślono poprez...

7.1 Specyfikacja interfejsu programistycznego

JeÂśli projekt, praca dotyczy systemu informatycznego, w dokumentacji umieszcza siĂŞ z reguÂły jedynie interfejs programistyczny (bÂądÂź jego fragmenty). PeÂłny kod moÂżna doÂłÂączyĂ¦ w zaÂłÂączniku.

```
private double losuj(int ile, double min, double max);
```

Metoda losuje liczbĂŞ z podanego zakresu. Przed zwrĂłceniem wartoÂści, losowanie powtarzane jest wybranÂą liczbĂŞ razy w celu zwiĂŞkszenia czasu obliczeĂ±.

- Parametry:

  ile okreÂśla ile rezy naleÂży losowaĂ¦ przed zwrĂłceniem liczby,

  min definiuje wartoÂśĂ¦ minimalnÂą,

  max definiuje wartoÂśĂ¦ minimalnÂą,

- WartoÂśĂ¦ zwracana: wylosowana liczba
- BÂłĂŞdy: w przypadku, gdy ile < 0, zgÂłaszany jest wyjÂątek WrongIleException

itd.
czasami warto omĂłwiĂ¦ wybrane fragmenty razem z implementacjÂą

```
1 double x = 2 ^ 1023-3 / 22;
2 int z = (int)x;
3 p = x - z;
4 ...
```

w pierwszej kolejnoÂści stosowana jest staÂła Krafta do redukcji zÂłoÂżonoÂści ciĂŞcia (linijka 2).

8. Instrukcja obsÂługi/Specyfikacja zewnĂŞtrzna

Instrukcja obsÂługi zbudowanego urzÂądzenia/programu komputerowego. DokÂładne wyjaÂśnienie zasad posÂługiwania siĂŞ tym, co zostaÂło otrzymane w efekcie przeprowadzonych prac. MoÂżna wykorzystaĂ¦ zrzuty ekranĂłw, scenariusze uÂżytkowe itp.

9. Rezultaty

Zobrazowanie i omĂłwienie wynikĂłw otrzymywanych wskutek zastosowania danego urzÂądzenia bÂądÂź aplikacji. Badanie ewentualnych parametrĂłw (takich jak dokÂładnoÂśĂ¦, czuÂłoÂśĂ¦...), czy teÂż zachowania w szczegĂłlnych sytuacjach. O ile to moÂżliwe tabelaryzacja rezultatĂłw oraz ich statystyczna interpretacja. Ocena zachowania zaproponowanego rozwiÂązania. Analiza moÂżliwych przyczyn wystÂąpienia bÂłĂŞdĂłw.

10. Podsumowanie

NawiÂązanie do celu pracy oraz postawionych zaÂłoÂżeĂ±.$PrĂbaocenyrealizacjicelu, poprzezw$

WstĂŞp wraz z podsumowaniem winny stanowiĂ¦ swego rodzaju klamrĂŞ, a nawet caÂłoÂśĂ¦ w takim rozumieniu, Âże przeczytanie wyÂłÂącznie tych dwĂłch rozdziaÂłĂłw tÂłumaczyĂ¦ powinno rozwaÂżany problem wraz z efektami otrzymanymi w efekcie prac, stanowiÂącymi jego rozwiÂązanie, bez wnikania w sposĂłb ich otrzymania (to zawiera czĂŞÂśĂ¦ Âśrodkowa).

[1] KrĂłtkie! 1-2 strony.

Bibliografia

[1] Anh Son Le, Tatsuya Suzuki, H. A. Evaluating driver cognitive distraction by eye tracking: From simulator to driving. *Transportation Research Interdisciplinary Perspectives 4* (2020).

[2] DĂaz, D., Yee, N., Daum, C., Stroulia, E., and Liu, L. Activity classification in independent living environment with jins meme eyewear. In *2018 IEEE International Conference on Pervasive Computing and Communications (PerCom)* (2018), pp. 1–9.

Dodatek

A. Dodatek A

W dodatku umieszczamy opis ewentualnych znanych algorytmĂłw, z ktĂłrych korzystamy proponujÂąc wÂłasnÂą metodologiĂŞ, opisanÂą w rozdziale ??. Wykaz pozycji literaturowych tworzymy w oddzielnym pliku `Praca.bib`. ChcÂąc siĂŞ odwoÂłaĂ¦ w tekÂście do wybranej pozycji bibliograficznej korzystamy z komendy `cite`. Efekt jej uÂżycia dla kilku pozycji jednoczeÂśnie to [?, ?, ?].

B. Dodatek B

Podstawowe kwestie techniczne dotyczÂące wzorĂłw, rysunkĂłw, tabel poniÂżej.

Wzory tworzymy w Âśrodowisku `equation`. ChcÂąc odwoÂłaĂ¦ siĂŞ do wybranego wzoru gdzieÂś w tekÂście naleÂży nadaĂ¦ mu stosownÂą, niepowtarzalnÂą i jednoznacznÂą etykietĂŞ, po ty by mĂłc np. napisaĂ¦ zdanie: ze wzoru B.1 wynika ...

$$c = a + b \tag{B.1}$$

Wzory zÂłoÂżone, charakteryzujÂące siĂŞ przypisaniem wartoÂści zmiennej w pewnych okolicznoÂściach tworzymy przy uÂżyciu otoczenia `eqnarray`. OdwoÂłanie do wzoru jak wczeÂśniej.

$$BW \quad = \quad \left\{ \begin{array}{ll} 1, & I(x,y) \geqslant T \\ 0, & I(x,y) < T \end{array} \right. , \tag{B.2}$$

NumeracjĂŞ rĂłwnaĂ±$mo\hat{A}natymczasowo(w\,danejlinijce)wy\hat{A}\hat{A}czy\breve{A}poprzezu\hat{A}ycie\backslash nonumb$

$$\begin{aligned} a_i &= a_{i-1} + a_{i-2} \\ &\quad +a_{i-3} \end{aligned} \tag{B.3}$$

B.1 Wstawianie rysunkĂłw

Rysunki umieszczamy w otoczeniu `figure`, centrujÂąc je w poziomie komendÂą `centering`. Rozmiary rysunku ustalamy w komendzie `includegraphics` dobierajÂąc wielkoÂśĂ¦ wzglĂŞdem rozmiaru strony lub bezwzglĂŞdnie np. w cm. Ponadto najpierw zapowiadamy pojawienie siĂŞ rysunku w tekÂście (czyli np. Na rysunku (Rys B.1) pracy, a dopiero pĂłÂźniej wstawiamy sam rysunek. Dodatkowo sterowaĂ¦ moÂżemy umiejscowieniem rysunku na stronie dziĂŞki parametrom `[!htb]` okreÂślajÂącym miejsce. Odpowiednio sÂą to: `here`, `top`, `bottom`.

DoÂłÂączajÂąc rysunki nie trzeba podawaĂ¦ rozszerzenia (wrĂŞcz jest to odradzane). JeÂśli rysunki znajdujÂą siĂŞ w katalogu *rysunki*, nie trzeba rĂłwnieÂż podawaĂ¦ ÂścieÂżki do nich.

B.2 Wstawianie tabelek

Analogicznie postĂŞpujemy z tabelkami, z tÂą rĂłÂżnicÂą Âże tworzymy jÂą w otoczeniu `table`. W nim natomiast samÂą tabelĂŞ definiujemy albo w Âśrodowisku

Rys. B.1: Logo WydziaÂłu InÂżynierii Biomedycznej.

`tabular`, albo `tabularx`. Podobnie z odwoÂłaniami w tekÂście: najpierw odwoÂłanie w Tab. B.1, a dopiero pĂłÂźniej sama tabela.

Tab. B.1: Opis nad tabelkÂą.

Kolumna 1	Kolumna 2	Kolumna 3	Kolumna 4
Wiersz 1			
Wiersz 2			
Wiersz 3			

C. Kwestie edytorskie

ZbiĂłr zasad pomocnych przy redagowaniu tekstu pracy wystarczajÂąco szczegĂłÂłowo przedstawia ksiÂąÂżka [?].

Uwaga! PiszÂąc pracĂŞ naleÂży zwrĂłciĂ¦ uwagĂŞ na nastĂŞpujÂące kwestie:

1. Prace piszemy w formie bezosobowej.

2. Unikamy okreÂśleĂ±*potocznych*, *spolszczeĂ±funkcjonujÂcychcodziennejmowieitp.PosÂug*

3. Podpisy pod rysunkami lub nad tabelami traktujemy jak zdania, a wiĂŞc powinny stanowiĂ¦ spĂłjnÂą caÂłoÂśĂ¦ oraz powinny zostaĂ¦ zakoĂ±*czonekropkÂ.Podobniewypunktowania*(*po* *czonykropkÂoilekoĂ* ± *czyzdanie*).

4. Do kaÂżdego rysunku, tabeli, pozycji bibliograficznej musi istnieĂ¦ odwoÂłanie w tekÂście pracy, przy czym do pierwszych dwĂłch musi siĂŞ ono pojawiĂ¦ zanim umieÂścimy rysunek/tabelĂŞ.

Bibliografia

[1] Anh Son Le, Tatsuya Suzuki, H. A. Evaluating driver cognitive distraction by eye tracking: From simulator to driving. *Transportation Research Interdisciplinary Perspectives 4* (2020).

[2] DĂaz, D., Yee, N., Daum, C., Stroulia, E., and Liu, L. Activity classification in independent living environment with jins meme eyewear. In *2018 IEEE International Conference on Pervasive Computing and Communications (PerCom)* (2018), pp. 1–9.