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研究課題名（和文）Automatic detection of level of students' engagement

研究課題名（英文）Automatic detection of level of students' engagement

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研究成果の概要（和文）：本研究は、ビデオ・データに基づいて学習者の集中力のレベルを自動的に認識することを目標とする。研究の意義として、システムが集中力の低下を認識できれば、ユーザーの適切な支援が可能となることを考えられている。

集中力のレベルは眼の動きに現れることを示しました。特に、まばたきの頻度およびまばたきの継続時間は集中力レベルと負の相関があり、眼の縦横比率および眼と画面の間の距離は集中力レベルと正の相関があると示した。集中力のレベルと眼の動きの関係をモデル化し、集中力のレベルを自動的に推定する方法を提案した。集中力レベルが大きくなると、集中している確率のモデルに基づく推定値も増大していることを示した。

研究成果の学術的意義や社会的意義

学術的有意性：顔のランドマークが集中力レベルの優れた指標であることを示した。また、顔のランドマークを自動的に推定のため使用できることも示した。

社会的重要性：最近、特にパンデミックによる、eラーニングがより多くの人々によって使用されており、提案された方法を用いて、そのユーザーのパフォーマンスを向上させる可能性があると考えられている。

研究成果の概要（英文）：The goal of this study is to automatically recognize the level of engagement of the user of an e-learning system based on video data. If the system can recognize the decrease in level of engagement, it may be possible to support the user appropriately.

In this research, we showed that the level of engagement is reflected in the eye movements. In particular, the frequency of blinking and the duration of blinks are found to be negatively correlated with the level of engagement, and the aspect ratio of the eye and the distance between the eye and the screen are found to be positively correlated with the level of engagement. We modeled the relationship between the level of engagement and eye movements, and proposed a probabilistic method for automatic estimation of the level of engagement. It was shown that as the level of engagement increased, so did the model-based estimate of the probability of engagement.

研究分野：人工知能

キーワード：Engagement Attention Behavior E-learning

1.研究開始当初の背景

The focus of this research is e-learning systems, which gain considerable attention in the recent decades. Particularly due to the rapid proliferation of mobile devices such as smart phones and tablets, students as well as life-long learners started to use a wide variety of e-learning tools to support their practice.

Despite their numerous advantages, the sense of remoteness and lack of interaction emerges as a significant challenge of e-learning systems. In that respect, most systems use adjustments such as rewards, badges, or levels, but they lack an accurate evaluation of learners' internal state (i.e. motivated, tired, confused, etc). In that respect, the learners, which cannot focus on the task, cannot benefit from these adjustments and it is necessary to have an accurate assessment of learners' level of engagement.

2.研究の目的

The goal of this research is to automatically estimate the level of engagement of e-learning system users in an objective, accurate and fast way.

3.研究の方法



First of all, for observing e-learners' behavior, we designed a set of experiments, recruited several participants from a diverse background and studied the ecological data. We designed three sorts of tasks such that each one exerts a different level of load or requires a different skill as (i) passive, (ii) semi-active and (iii) active.

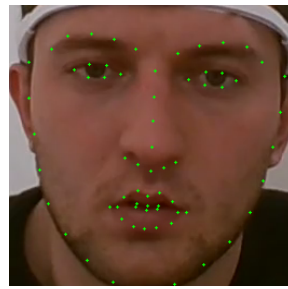
Specifically, in the passive task, the participants watch a slide show of images, which are selected from a benchmark saliency data set. The subjects are told that they will be given a memory test afterwards as a motivation to attend the images but no test is given. This task is considered to be similar to passive online learning and on-demand tools.

In the semi-active task, the participants listen to the narration of a story in English accompanied by illustrations, requiring listening comprehension and inference skills. At the end of each story, a small quiz is given. We consider the narration part of this task to be passive, where the participants need to comprehend the information, and the quiz to be active, which requires reasoning, deduction, and inference.

The active task is Wisconsin card sorting, which is a common tool in neuropsychology for examining the functioning of the frontal lobe. The test requires users to match a stimulus with one of the four options based on an undisclosed rule, which changes at uneven steps. This task requires strategic planning and organized search skills, as well as utilization of feedback, modulation of impulsive response, and directing behavior toward a goal.

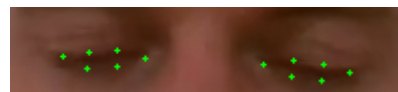
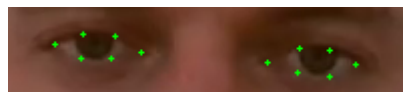
The ground truth for the level of engagement is obtained by manual annotation. Namely, two licensed teachers (i.e. coders) watched video clips recorded from the e-learners as they carry out the aforementioned tasks. The coders evaluated the clips according to the apparent level of engagement of the participants. The coders assigned each clip an engagement label e on a Likert scale from 1 to 5, where $e = 1$ denotes "disengaged" and $e = 5$ represents "engaged". We carried out a methodological analysis quantifying

the degree of agreement between the coders and confirmed that they have a sufficient level of agreement.



In the analysis phase, we derived the ocular landmarks (the point on the face that depict the borders of the eyes) from the video recordings. Using these landmarks, we study spontaneous blink patterns. In blink detection, we employ the simple and yet powerful real-time blink detection method proposed by Soukupová

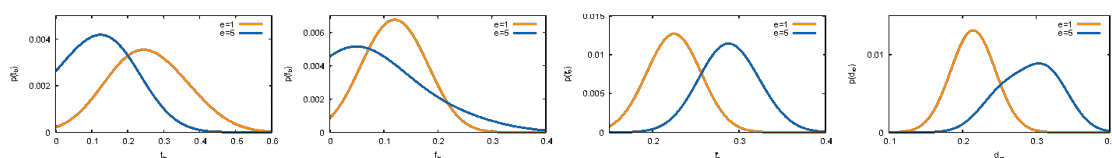
and Cech (2016). Specifically, this method is based on the changes in aspect ratios of the right and the left eye. An SVM classifier on sample blinking and non-blinking patterns from several data sets and the blinks are identified from the average aspect ratio of the two eyes.



Subsequent to the detection of ocular landmarks and blinks, we define a set of four features derived thereof as duration of blinks, frequency of blinks, average aspect ratio for open eyes, and interocular breadth.

We employed polyserial correlation coefficient to assess the relevance of the four features from the standpoint of engagement. Computing polyserial correlation coefficient ρ for duration and frequency of blinks, we demonstrate that they have a -mild- negative correlation with engagement. This finding is in line with the previous works in literature, which state that blinking helps humans disengage from the outside stimuli, in favor of the other cognitive processing (i.e. mind wandering); as well as the fact that increased workload causes a higher blinking rate in the long term. On the other hand, based on polyserial correlation coefficient, the interocular breadth and eye aspect ratio are shown to have a somewhat stronger positive correlation with the apparent level of engagement. In other words, as the level engagement increases, interocular breadth and normalized eye size increase as well. This indicates that when the user is concentrated on the task, his/her face is closer to the screen and; he/she looks at the screen with eyes wider open.

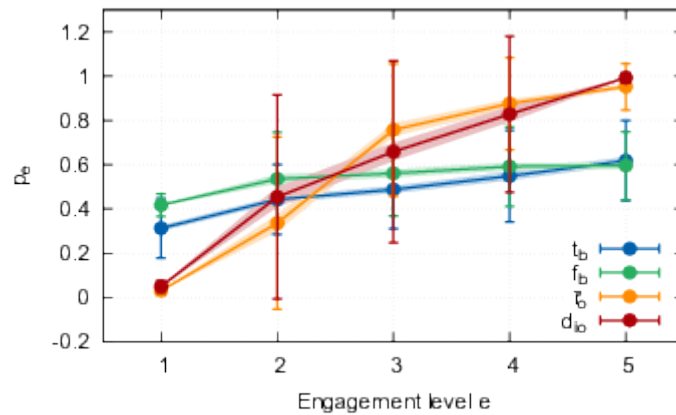
Subsequent to verifying that the proposed features present credible correlation with the assigned levels of engagement, we proposed a method to probabilistically assess the level of engagement. To that end, we derived probability density function (pdf) of the features from their respective empirical observations. In doing that, we utilize kernel density estimation (KDE), which is one of the most popular non-parametric methods in estimating the underlying pdf of a set of observations. However, in practice, multivariate kernel density estimation is usually restricted to 2-D due to the curse of dimensionality. In order to tackle with this issue, we proposed employing a set of 4 1D distributions, after certifying the conditional independence of feature distribution. Based on relative entropy distance, we inferred that there is a reasonable degree of independence between all pairs and that the curse of dimensionality can be overcome using a decomposition of individual density distributions.



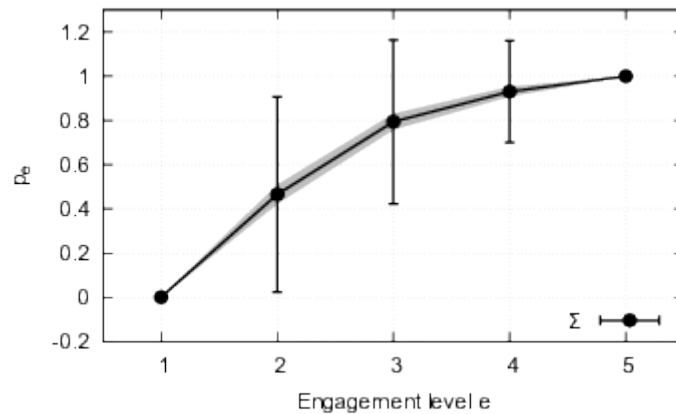
4. 研究成果

First of all, for evaluating the effectiveness of each particular feature, we applied the probabilistic approach to individual features. Next, by applying the estimation method on the set of all features, we determined the potentially optimum performance.

The below figure demonstrates the probability of being engaged (p_e) based on each of the four features. From this figure, it is clear that probability of being engaged is monotonically increasing for growing values of ground truth label (1~5) for all features, although the rate of increase varies between the features. Nevertheless, the overall tendency still presents supporting evidence for the efficacy of the proposed features, particularly for interocular distance and the eye aspect ratio, which are in line with the conclusions based on polyserial correlation values.



As presented in the figure below, by integrating the information from all the features, we obtained a clear improvement in estimation of engagement. As expected, the values of probability of being engaged (p_e) obtained by the integration of all features is monotonically increasing. Also, it yields a clear separation between values of p_e relating $e \in [1, 2]$ (i.e. disengaged or poorly engaged) and $e \in [4, 5]$ (i.e. moderately engaged to fully engaged). In particular, we see that if the user is not engaged, then p_e is 0, whereas it increases steeply to around 0.90 as $e \geq 4$. These findings suggest that by estimating p_e with the proposed method and setting a threshold at some value around 0.50, we can detect the engagement levels below average and above average with a satisfactory accuracy.



5. 主な発表論文等

〔雑誌論文〕 計6件（うち査読付論文 6件/うち国際共著 2件/うちオープンアクセス 5件）

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| 1. 著者名 Consortium for the Physics and Psychology of Human Crowd Dynamics (including Zeynep Yucel and 38 others) | 4. 巻 4 |
| 2. 論文標題 A glossary for research on human crowd dynamics | 5. 発行年 2019年 |
| 3. 雑誌名 Collective dynamics | 6. 最初と最後の頁 1-13 |
| 掲載論文のDOI (デジタルオブジェクト識別子) 10.17815/CD.2019.19 | 査読の有無 有 |
| オープンアクセス オープンアクセスとしている (また、その予定である) | 国際共著 該当する |
| 1. 著者名 Zanlungo Francesco, Yucel Zeynep, Kanda Takayuki | 4. 巻 14 |
| 2. 論文標題 Intrinsic group behaviour II: On the dependence of triad spatial dynamics on social and personal features; and on the effect of social interaction on small group dynamics | 5. 発行年 2019年 |
| 3. 雑誌名 PLOS ONE | 6. 最初と最後の頁 e0225704 |
| 掲載論文のDOI (デジタルオブジェクト識別子) 10.1371/journal.pone.0225704 | 査読の有無 有 |
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| 1. 著者名 Yucel Zeynep, Zanlungo Francesco, Feliciani Claudio, Gregorj Adrien, Kanda Takayuki | 4. 巻 14 |
| 2. 論文標題 Identification of social relation within pedestrian dyads | 5. 発行年 2019年 |
| 3. 雑誌名 PLOS ONE | 6. 最初と最後の頁 e0223656 |
| 掲載論文のDOI (デジタルオブジェクト識別子) 10.1371/journal.pone.0223656 | 査読の有無 有 |
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| 1. 著者名 Parisa Supitayakul, Zeynep Yucel, Akito Monden, Pattara Leelaprute | 4. 巻 3 |
| 2. 論文標題 Identification of behavioral variables for efficient representation of difficulty in vocabulary learning systems | 5. 発行年 2020年 |
| 3. 雑誌名 International Journal of Learning Technologies and Learning Environments | 6. 最初と最後の頁 51-60 |
| 掲載論文のDOI (デジタルオブジェクト識別子) なし | 査読の有無 有 |
| オープンアクセス オープンアクセスとしている (また、その予定である) | 国際共著 - |

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| 1. 著者名 Yucel Zeynep, Koyama Serina, Monden Akito, Sasakura Mariko | 4. 巻 36 |
| 2. 論文標題 Estimating Level of Engagement from Ocular Landmarks | 5. 発行年 2020年 |
| 3. 雑誌名 International Journal of Human-Computer Interaction | 6. 最初と最後の頁 1527-1539 |
| 掲載論文のDOI (デジタルオブジェクト識別子) 10.1080/10447318.2020.1768666 | 査読の有無 有 |
| オープンアクセス オープンアクセスではない、又はオープンアクセスが困難 | 国際共著 - |

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| 2. 論文標題 An algorithm for automatic collation of vocabulary decks based on word frequency | 5. 発行年 2020年 |
| 3. 雑誌名 IEICE Transactions on Information and Systems | 6. 最初と最後の頁 1865-1874 |
| 掲載論文のDOI (デジタルオブジェクト識別子) 10.1587/transinf.2019EDP7279 | 査読の有無 有 |
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| 1. 発表者名 Zeynep Yucel, Francesco Zanlungo, Takayuki Kanda |
| 2. 発表標題 Gender profiling of pedestrian dyads |
| 3. 学会等名 Traffic and Granular Flow (国際学会) |
| 4. 発表年 2019年 |

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| 1. 発表者名 Francesco Zanlungo, Luca Crociani, Zeynep Yucel, Takayuki Kanda |
| 2. 発表標題 The effect of social groups on the dynamics of bi-directional pedestrian flow: a numerical study |
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| 4. 発表年 2019年 |

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| 1 . 発表者名 Serina Koyama, Zeynep Yucel, Akito Monden |
| 2 . 発表標題 Quantitative evaluation of the relation between blink related features and engagement |
| 3 . 学会等名 European Conference on Visual Perception (国際学会) |
| 4 . 発表年 2019年 |

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| 1 . 発表者名 Parisa Supitayakul, Zeynep Yucel, Akito Monden, Pattara Leelaprute |
| 2 . 発表標題 Assessing the effect of varying word classes on behavioral variables in technology mediated vocabulary learning |
| 3 . 学会等名 International Conference on Learning Technologies and Learning Environments (国際学会) |
| 4 . 発表年 2019年 |

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| 1 . 発表者名 Adrien Gregorj, Zeynep Yucel, Sunao Hara, Akito Monden, Masahiro Shioni |
| 2 . 発表標題 A signal processing perspective on human gait: Decoupling walking oscillations and gestures |
| 3 . 学会等名 International Conference on Interactive Collaborative Robotics (国際学会) |
| 4 . 発表年 2019年 |

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| 1 . 発表者名 Pimwalun Witchawanitchanun, Zeynep Yucel, Akito Monden, Pattara Leelaprute |
| 2 . 発表標題 Effect of grasping uniformity on estimation of grasping region from gaze data |
| 3 . 学会等名 International Conference on Human-Agent Interaction (国際学会) |
| 4 . 発表年 2019年 |

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| 1. 発表者名 Tanakan Pramot, Zeynep Yucel, Akito Monden, Pattara Leelaprute |
| 2. 発表標題 Effect of motivation on gaze behavior over time |
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| 4. 発表年 2018年 |

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| 1. 発表者名 Hoang Nguyen, Serina Koyama, Zeynep Yucel, Akito Monden, Mariko Sasakura |
| 2. 発表標題 Estimation of affect scores accounting for user responsiveness |
| 3. 学会等名 Annual Conference of the Robotics Society of Japan |
| 4. 発表年 2018年 |

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| 1. 発表者名 Parisa Supitayakul, Zeynep Yucel, Akito Monden, Pattara Leelaprute |
| 2. 発表標題 Investigating effect of stimulus modality on recollection rate in e-learning systems |
| 3. 学会等名 International Conference on Learning Technologies and Learning Environments (in press) (国際学会) |
| 4. 発表年 2020年～2021年 |

〔図書〕 計0件

〔産業財産権〕

〔その他〕

研究代表者ホームページ
<https://yucelzeynep.github.io/index.html>

6. 研究組織

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|--|---------------------------|-----------------------|----|
| | 氏名 (ローマ字氏名) (研究者番号) | 所属研究機関・部局・職 (機関番号) | 備考 |
|--|---------------------------|-----------------------|----|

7. 科研費を使用して開催した国際研究集会

〔国際研究集会〕 計0件

8. 本研究に関連して実施した国際共同研究の実施状況

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| 共同研究相手国 | 相手方研究機関 |
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