An Estimation Method of Intellectual Work Performance by Using Physiological Indices

Agenda
1. Background / Purpose
2. Method
3. Experiment
4. Result / Discussion
5. Future

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The evaluation method of Intellectual productivity is required

Requirements
The evaluation can be performed …
- under the environment like office
- by using various cognitive tasks

The evaluation by using contactless-measurable physiological indices is suitable
- These indices can be measured under various environments.
- They reflect cognitive load

There is few method which can evaluate intellectual productivity directly with these indices
Purpose

- The task performance evaluation method by using physiological indices

The method...
- evaluates the performance of cognitive task simulating office work
- employs machine learning: SVR, Random forest
- employs pupil diameter and heart rate variability because they are contactless-measurable

If the method can be developed, intellectual productivity can be employed as the control variable of the control system such as BEMS (building energy management system)
To acquire properly training data, various task performance were measured. The average of these accuracy of the regression models were evaluated by using training data.
Physiological indices

• Pupil diameter
  Measurement with Infrared camera

• Heart rate variability
  Measurable by using camera (future)
  This study employed electrodes

• The feature values were extracted in 5-minute timeframe with shifting it every 1 minute.
Cognitive task – Receipt Classification Task

![Receipt Classification Task Diagram]

Day 1-10

<table>
<thead>
<tr>
<th>Store</th>
<th>-5,000yen</th>
<th>-50,000yen</th>
<th>50,001yen -</th>
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Day 11-20

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Day 21-31

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Experiment

- Protocol

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Practice</th>
<th>Phase A</th>
<th>rest</th>
<th>Phase B</th>
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<tbody>
<tr>
<td>10min.</td>
<td>10min.</td>
<td>30min.</td>
<td>10min.</td>
<td>30min.</td>
</tr>
</tbody>
</table>

- 1st day…practice  2nd day…measurement (described above)
- 27 Japanese university students participated
- In the practice, the participants were instructed to perform the task at the slowest speed.
- Phase A : either Pace-up or Pace-down Phase at random
  Phase B : the other
  (to get counterbalance of ordering effect)
Result: task performance

➢ It was confirmed that both Pace-up and Pace-down were performed properly.
result: accuracy of 2 machine learning models

- The accuracy of SVR was higher significantly than that of Random Forests
Result: coefficients of feature variables

- Pupil diameter had positive correlation with task performance
  - The result was supported by the study conducted by Poock [1]

- Heart rate variability had negative correlation.
  - According to Mulder [2], the higher the difficulty of a cognitive task gets, the lower the power of LF gets. The result supports this.

Average of coefficients of feature variables

<table>
<thead>
<tr>
<th>Pupil diameter</th>
<th>LF</th>
<th>LF/HF</th>
<th>HF</th>
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</thead>
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<tr>
<td></td>
<td>2.00</td>
<td>-0.98</td>
<td>-0.71</td>
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Discussion: the effect of multivariate regression model - pupil diameter

plural feature variables can deal with individual differences

Subject No.10:
Ex. High contribution of pupil diameter

<table>
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<th>Pupil diameter</th>
<th>LF</th>
<th>LF/HF</th>
<th>HF</th>
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</thead>
<tbody>
<tr>
<td>3.66</td>
<td>0.51</td>
<td>-0.66</td>
<td>-0.99</td>
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\[ MSE = 0.021, R^2 = 0.969 \]
Discussion: the effect of multivariate regression model – Heart rate variability

plural feature variables can deal with individual differences

Subject No.4 :
Ex. Low contribution of pupil diameter, High contribution of heart rate variability

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<th>LF/HF</th>
<th>HF</th>
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<tbody>
<tr>
<td>-0.02</td>
<td>-3.05</td>
<td>-2.06</td>
<td>-3.38</td>
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※normalized to \([-1,1]\)

\[MSE = 0.074, R^2 = 0.878\]
Conclusion

• The accuracy of SVR was significantly higher than Random forest

• Multivariate regression model
  ▫ Pupil diameter had high contribution to the model
  ▫ Heart rate variability had high contribution while low contribution of pupil diameter was found in some subjects.

➢ Multivariate regression model can deal with individual difference.

• In order to develop the more quantitative and objective evaluation method

  Need to consider…
  ▫ the stress effect in long term measurement.
  ▫ the accuracy of this model by using various cognitive tasks

Thank you for your attention
Discussion: Stress affects the accuracy of models

Stress changes the physiological responses, which affects the accuracy of models

Ex. The case of low estimation accuracy

- The proposed method (SVR)
- After adding dummy variable D
  D = 1 (Pace-up), -1 (Pace-down)

\[ \text{MSE} = 0.167, R^2 = 0.608 \]
\[ \text{MSE} = 0.053, R^2 = 0.917 \]
SVRのパラメータ

• カーネル：ガウシアンカーネル

• パラメータ探索範囲…$10^3 = 1000$パターン
  △ $-3 \leq \log_2 C \leq 6$ （マージンから逸脱した場合のペナルティの大きさ）
  △ $-6 \leq \log_2 \sigma \leq 3$ （ガウシアンカーネルの形状）
  △ $-10 \leq \log_2 \varepsilon \leq -1$ （許容範囲の広さ）

• 探索範囲の影響
  △ 探索範囲を2倍、探索幅を1/2（$40^3 = 64000$パターン）にして推定精度の低かった3名の被験者で再度推定精度をEvaluation

<table>
<thead>
<tr>
<th></th>
<th>拡大前</th>
<th>拡大後</th>
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</thead>
<tbody>
<tr>
<td>MSE</td>
<td>0.188</td>
<td>0.186</td>
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<tr>
<td>$R^2$</td>
<td>0.652</td>
<td>0.660</td>
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