OECD Halden Reactor Project

Presenter
Per Øivind Braarud

Contact
Per.Oivind.Braarud@ife.no

Dynamic estimation of operator cognitive workload from operators' speech and human-system-interface logs. (Preliminary Results – Work in Progress)

Per Øivind Braarud, IFE

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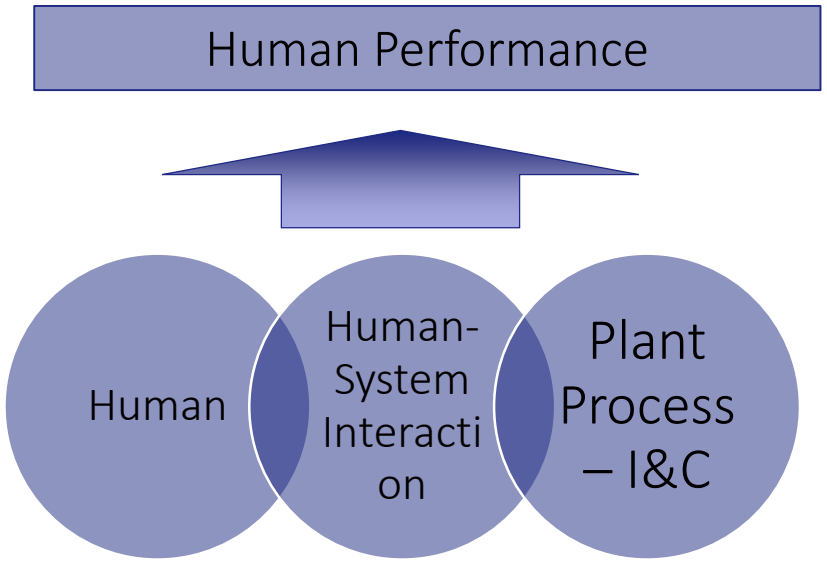
Joint effort between OECD Halden Reactor Project MTO and IFE Strategic Institute Initiative: “Smart-Human-System-Evaluation”

Improving the basis for Human Factors investigation through automated utilisation of diverse data sources



- People involved (from IFE) include:
  - Emil Wingstedt
  - Terje Bodal
  - John Einar Hulsund
  - Espen Nystad
  - Mike Louka
  - Christer Nihlwing
  - Håkan Svengren
  - Per Øivind Braarud

Study Purpose

- Improve Workload Assessment
  - Precision – capture dynamics of work
  - Automated
  - Non-intrusive on human behavior and performance
  - Limited need for special equipment

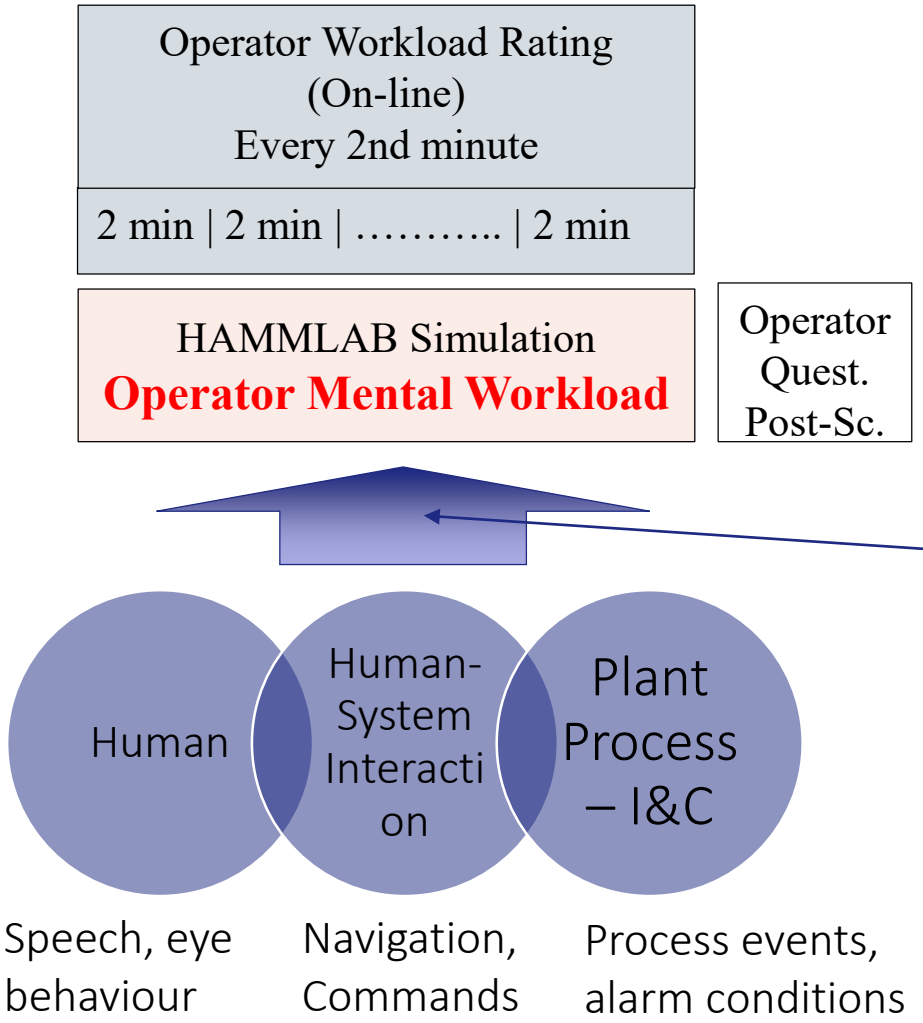
- for application in
  - Operators' simulator training
  - Control room validation
  - Adaptive operator support and human-machine control systems

Background: Estimation of cognitive workload

- Promising results from highly controlled experiments studying simple tasks
- A few examples:
  - Speech: Simple individual tasks such as Stroop test, Three levels of workload were classified from speech features with an accuracy of 78.9% (Yin et al, 2007) and 84.4% (Yap et al, 2010).
  - System variables and User interaction: Workload measured by air traffic controllers' flight clearances (Tobaruela et al., 2014).
  - Eye Behavior: Pupil size and blink duration correlated positively with the level of mental workload (Ahlstrom & Friedman-Berg, 2006).
  - Physiological data: Brain activity (Wilson & Russell, 2003)

- Unknown: Realistic settings - such as full scope training simulators
  - Where operators decide strategy and timing of actions, move, utilize the interface and apply procedures realistically, communicate according to normal procedures and according to the given work status

Workload Assessment in realistic settings



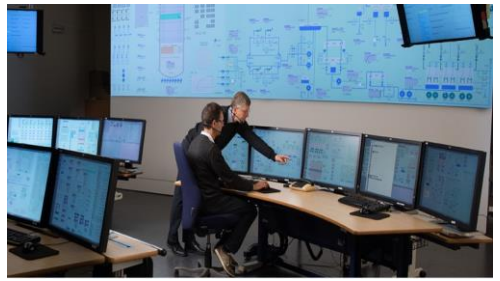
Most popular technique is subjective rating – often post sessions Post-Scenario, low precision, utility?

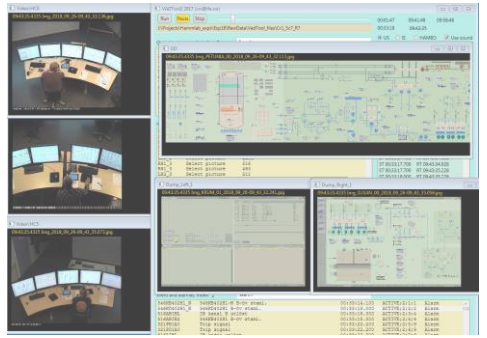
During work, Hypothesized high precision and high utility

Simulator Experiment - Overview of Method

- 6 crews – 18 operators
  - Supervisor, Reactor Operator, Turbine Operator
- 12 scenarios (varying from about 15 to 45 minutes)
  - 4 Sub system testing
  - 4 Targeted integrated testing
  - 4 Full scale integrated testing (ISV)
- 2 Expert Observers

- HAMBO Boiling Water Reactor Simulator
  - Simulates Forsmark 3



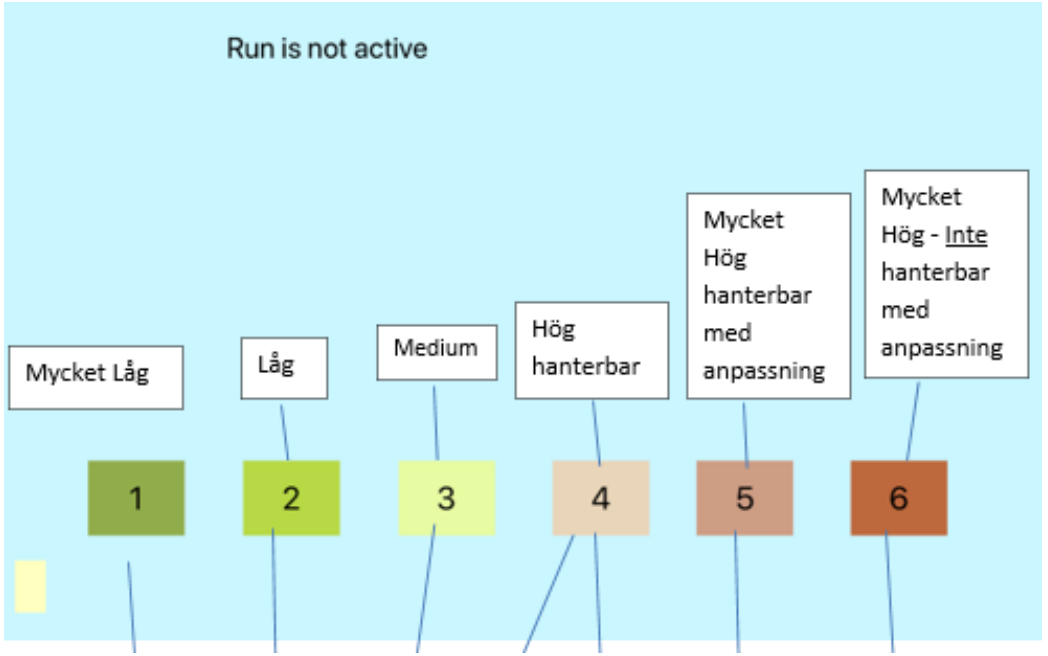


Operator Rating Scale applied during scenarios

- Operator's rating of mental workload during scenario used for
  - Training a machine learning algorithm
  - Reference to check the accuracy of algorithm's estimation

- Operator's rating of mental workload experienced
  - Every 2nd minute
  - For analysis, simplified to three categories of cognitive workload
    - **Low**
    - **Medium**
    - **High**

On-line rating Tool (ipad)



- Operators Workload Rating during scenarios

- Example Results

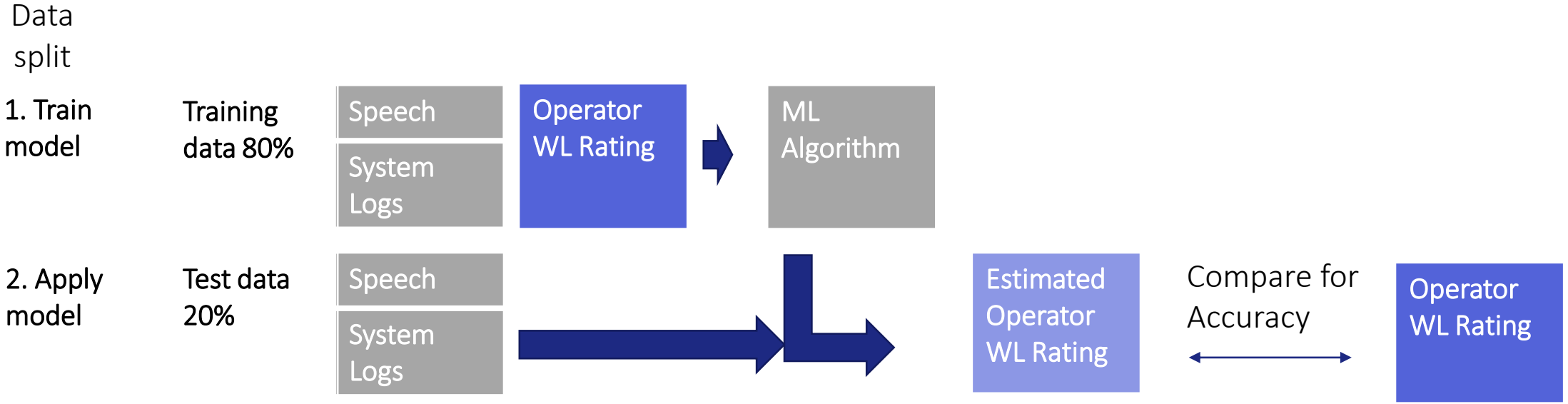
Features for WL prediction extracted from data

- Simulator logs
  - Incoming Alarms
  - Alarms acknowledged
  - Operator Interface Navigation
  - Operator Commands

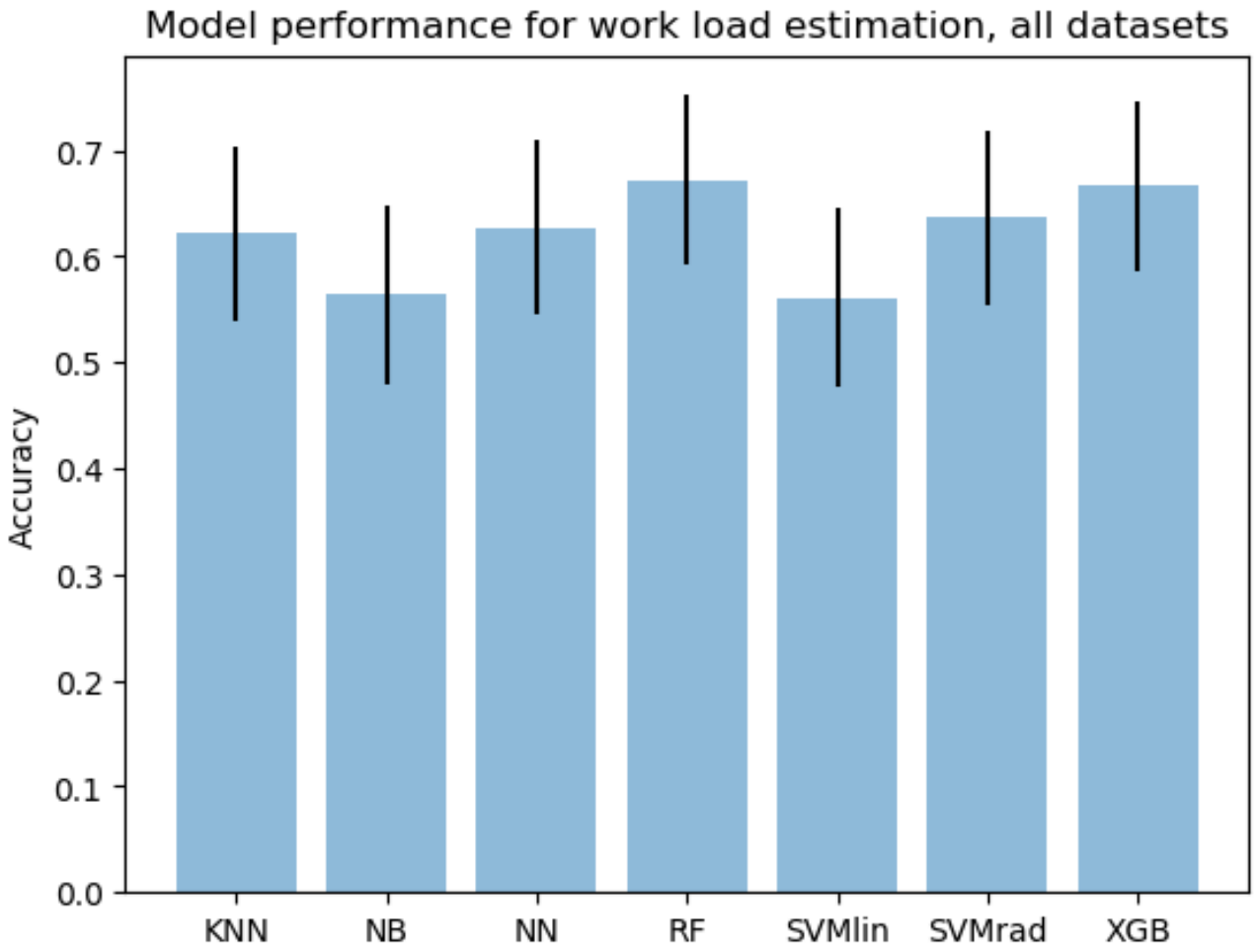
- Speech (Operator's communication) recording during work
  - Fundamental frequency ("f0")- average and peak
  - Intensity, amplitude average and peak
  - Pauses
  - Articulation rate

Analysis:

- Machine Learning Classification (e.g., Random Forest - Tree Model)
- Random split data: Training set – 80%, Test set 20%
- Train a model the training data set, Repeated cross-validation (10-fold, 5 times)
- Predicted Workload for the test data using the best model.



Accuracy of test data estimation for seven commonly applied machine learning algorithms

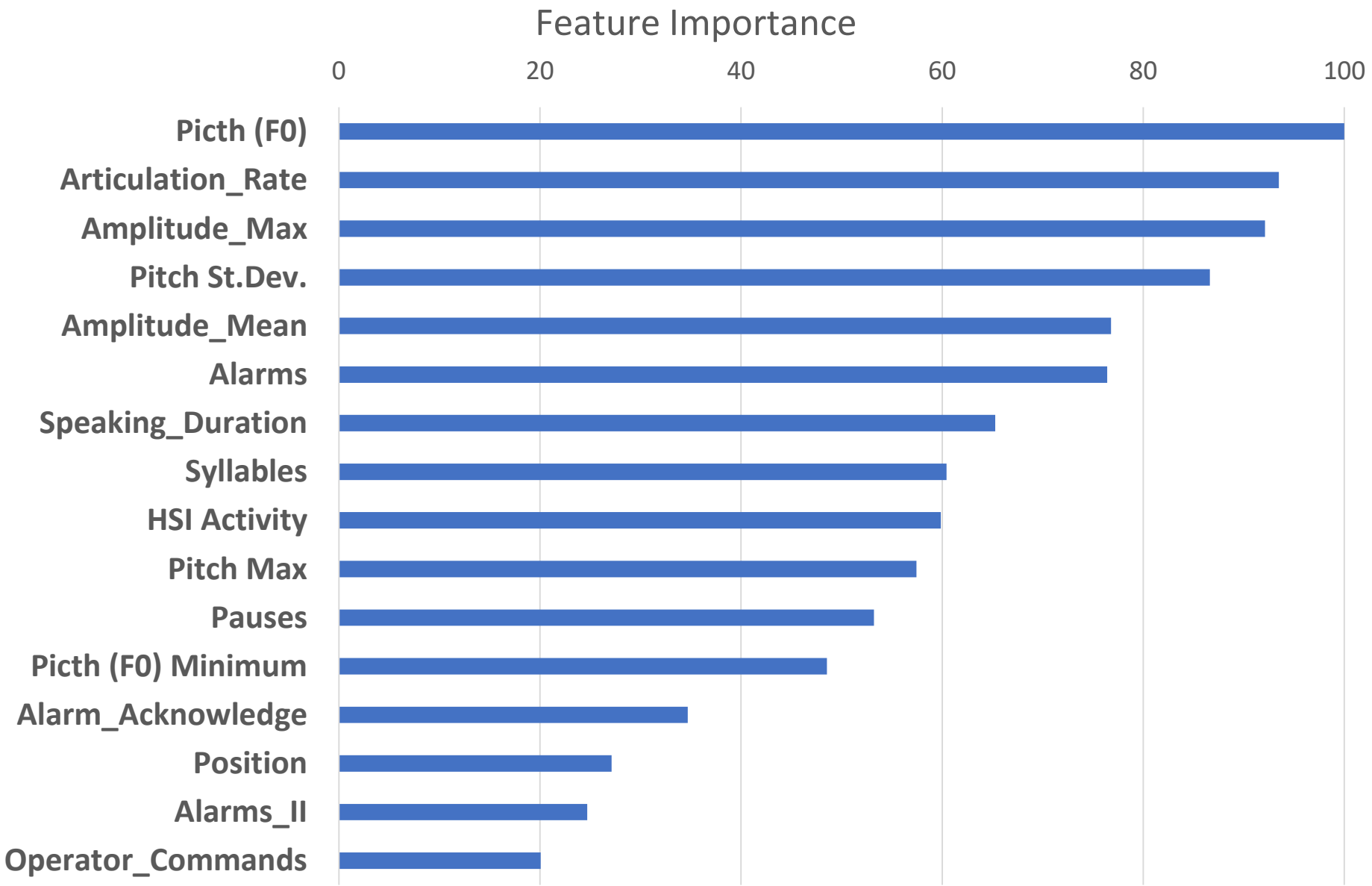


“Confusion” Matrix - Random Forest Algorithm

- Accuracy: 0.67

		Operators Rating during scenarios		
		Low (240)	Medium (281)	High (34)
Estimated by ML from Speech and System logs	Low	160	69	8
	Medium	80	212	25
	High	0	0	1

Variable (feature) importance



Conclusion

- Both Features from operators communication and features from simulator logs related to workload rating
- Promising - for further research and development
  - Future work can include other data, e.g., Eye Behavior Features
- Workload is a “test case”, A number of other human performance phenomena can be addressed by similar approach

Halden Project – MTO Research program proposal 2021-2023

1 HUMAN PERFORMANCE

- 1.1 Operator Performance in Digital Control Rooms
- 1.2 Crew Factors, Leadership and Role Independence in Nuclear Control Rooms
- 1.3 Decision making under uncertainty
- 1.4 Event Investigations – the Added Perspective of Successes
- 1.5 Digital Training Partner – Principles for Utilising New Scenario-based Training Technology
- 1.6 The Human Performance Data Repository

2 DIGITAL I&C - SAFETY ASSURANCE

- 2.1 Planning, Managing and Visualising Safety Assurance
- 2.2 Risk-Informed Safety Assurance
- 2.3 Evidence Collection, Evaluation and Combination for Safety Assurance

3 CONTROL ROOM DESIGN & EVALUATION

- 3.1 Augmented Reality for On-Site Control Room Assessment of Ergonomic and Regulatory Compliance
- 3.2 Lessons Learned on Control Room Validation
- 3.3 The Impact of Overview Displays on Human Performance

4 HUMAN-AUTOMATION COLLABORATION

- 4.1 Human Performance in Operation of Advanced Reactors
- 4.2 Automation Transparency in Future Plants
- 4.3 New Strategies for Problem-Solving in Future Hybrid Teams

5 DIGITAL SYSTEMS FOR OPERATIONS AND MAINTENANCE

- 5.1 Efficient Data Management with Data Lake technology
- 5.2 Advanced Condition-Based Maintenance using Digital Twin Technology
- 5.3 New Ways of Working, Organisational Capabilities for Harvesting the Digitalisation Potential
- 5.4 Advanced Condition Monitoring for Decision Support
- 5.5 Improved Safety, Quality and Efficiency through Advanced Outage Management

6 DIGITAL TRANSFORMATION OF NUCLEAR DECOMMISSIONING

- 6.1 Spatial Computing and Augmented Reality for Hazard Mapping and Visualisation
- 6.2 Automated Assessment of Field Worker Performance using VR and AR-based Simulator Training
- 6.3 Digitally-Enhanced Safety Assurance for Decommissioning
- 6.4 Enabling Robotic and Remote Operations
- 6.5 Overview Displays for Decommissioning of Nuclear Reactors

7 CYBER SECURITY FOR MAIN CONTROL ROOMS

- 7.1 Digital Systems Architecture and Threat Landscape
- 7.2 Incident Detection and Response using Simulation Modelling and Tools
- 7.3 Human Behaviour during Incident Response

8 PROGRAMME BASIS, MTO RESEARCH

- 8.1 The MTO Laboratories
- 8.2 Tools and Methods
- 8.3 Maintenance and Operation of the MTO Laboratories

Thank you for your attention

Per Øivind Braarud

Senior Researcher

Per.Oivind.Braarud@ife.no