Automaatiopäivät24

Extended Abstracts

13-14 April 2021
Virtual Event

Edited by
David Hästbacka and Esko Juuso

New safety concepts for autonomous mobile machines

Authors: Timo Malm, VTT, Finland, timo.malm@vtt.fi
Risto Tiusanen, VTT, Finland, risto.tiusanen@vtt.fi
Eetu Heikkilä, VTT, Finland, eetu.heikkila@vtt.fi
Toni Ahonen, VTT, Finland, toni.ahonen@vtt.fi
Janne Sarsama, VTT, Finland, janne.sarsama@vtt.fi

Keywords: safety, autonomous, mobile machine

Background

Many kinds of autonomous ground vehicles are becoming more common as new technical solutions are applied even more successfully. Driverless cars have been featured and they have already tens of millions kilometers documented driving. Autonomous mobile machines have been successful in some specific applications related e.g. to agriculture, ports and mines. There are already some standards for autonomous systems, which shows that the associated technological fields are expecting increase in autonomy. However, so far, autonomous mobile machines have been applied in limited conditions and the final steps to full autonomy need to be done.

There are several concepts and terms for autonomous ground vehicles in different applications. The following terms are applied commonly to refer autonomous vehicles: driverless cars, unmanned ground vehicles (UGV), driverless industrial trucks, autonomous machines, highly automated agricultural machines and automated guided vehicles (AGV). There are also several levels for autonomy from manual to conditionally automated and furthermore autonomous operation. The Society of Automotive Engineers (SAE) has six levels of autonomy from 0 to 5. Level 5 is associated to full autonomy.

Aims

The aim of this study is to show basic concepts for autonomous mobile machines, which are applied in industrial outdoors applications.

Materials and methods

The article includes literature review, study of standards and compilation of findings in recent projects at VTT.

Results

Fig. 1 shows an example of autonomous mobile system, which includes autonomous operating zone, monitored manned machines, monitored persons and autonomous mobile machines. Unmonitored machines and persons are outside the autonomous operating zone. Vehicles and persons can enter the autonomous operating zone when it is safe. There are several means to establish safe operation, like, changing operating mode or dividing autonomous area into several zones with their own area access control systems.

Three standards related to autonomous mobile systems show different aspects to autonomy. Autonomous earth moving machine standard (ISO 17757:2019) shows a model of complete autonomous system, which have central control to monitor individual machines and persons. Driverless industrial truck standard (ISO 3691-4:2020) gives examples of different levels of isolation and safety functions with functional safety requirements. Highly automated agricultural machine standard (ISO 18497:2018) gives information about on-board safety systems of autonomous machines.

Safety measures of autonomous mobile machines is based on

- fleet management and supervisory system, which gives tasks and keeps the machines in permitted area and prevents impacts, with other automated machines,
- area access control, which can permit persons and machines to enter a specific area,
- on-board safety system, which monitors neighborhood and maintains safety by applying relevant safety functions (e.g. stop command).

Safety of driverless cars is typically based on on-board safety system, which detects objects that can cause collision hazard. In autonomous mobile machines on-board safety systems are applied to detect objects, which are beside the autonomous mobile machine in a hazardous position. Typical sensors for object detection are laser scanners, lidars, radars and tactile sensors. Cameras are common in cars.
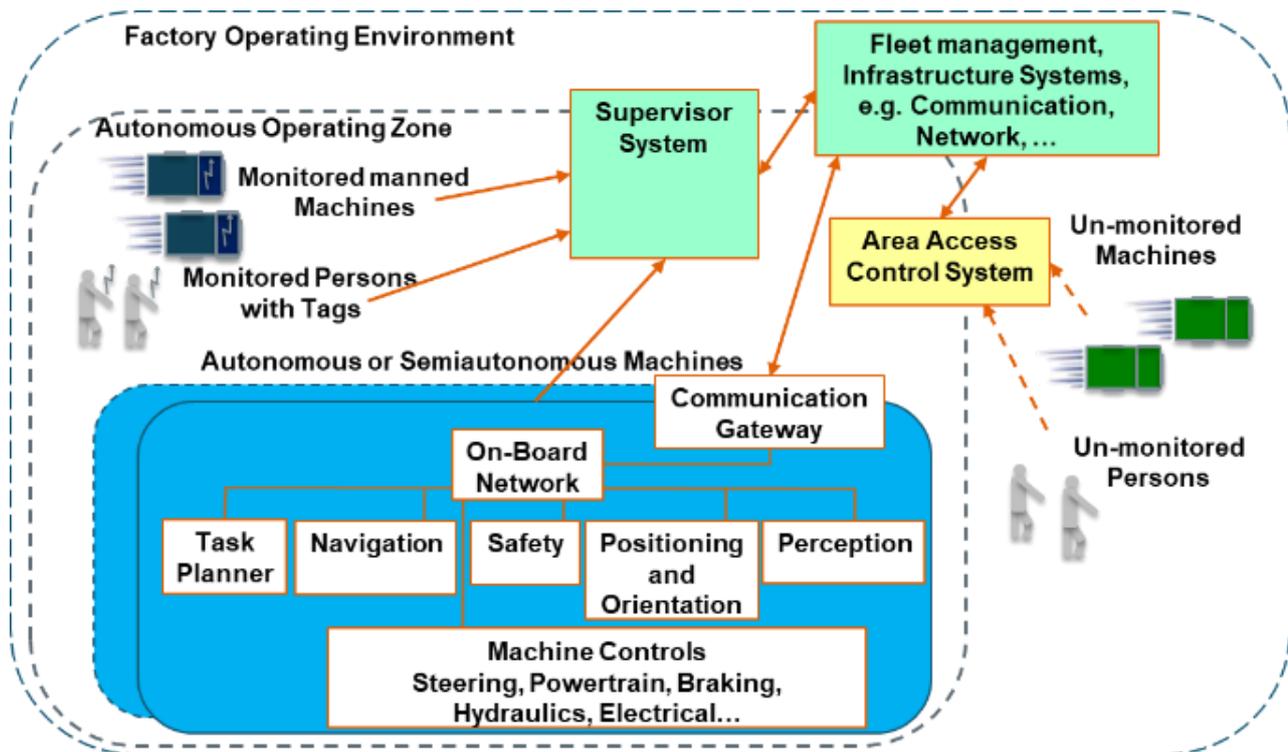

Fig. 1 Autonomous mobile machine system example according to ISO 17557:2019 (modified).

The autonomous mobile machines are controlled and monitored by fleet management, supervisory and area access control systems, which are essential part of the autonomous system safety. If autonomous area could be isolated totally and no persons were allowed to enter the automated area in automated mode, then most of the hazards inside the area can be under control. However, usually it is not practical to prevent the access completely, but the conditions when the entrance is safety, need to be arranged.

New technologies, like, novel sensors for perception and positioning, navigation systems and artificial intelligence are applied in conjunction to ensure safety. There is still uncertainty how safely the systems can operate in all conditions. Taeihagh and Lim have reported 2019 that driverless cars have had minor accidents in California about every 67 000 km and according to Wikipedia ("List of self-driving car fatalities") in the world there are at least 5 fatalities. The systems are not yet perfect and therefore more research is needed to integrate and interlock the systems to operate safely even if one part of the system fails.

Conclusions

The safety approaches can be divided into three groups: isolation of autonomous mobile machines, safe separation between machines and objects and rules increased situational awareness for persons and machines at the automated area.

References

ISO 17757:2019. Earth-moving machinery and mining — Autonomous and semiautonomous machine system safety. 36.

ISO 3691-4:2020. Industrial trucks — Safety requirements and verification — Part 4: Driverless industrial trucks and their systems. 84.

ISO 18497:2018. Agricultural machinery and tractors — Safety of highly automated agricultural machines — Principles for design. 18.

Taeihagh, A & Lim, H. S. M,. Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks, Transport Reviews, 2019. 39:1, 103-128, DOI: 10.1080/01441647.2018.1494640.

Safety risk sources of autonomous mobile machines

Authors: Timo Malm, VTT, Finland, timo.malm@vtt.fi
Risto Tiusanen, VTT, Finland, risto.tiusanen@vtt.fi
Eetu Heikkilä, VTT, Finland, eetu.heikkila@vtt.fi
Toni Ahonen, VTT, Finland, toni.ahonen@vtt.fi
Janne Sarsama, VTT, Finland, janne.sarsama@vtt.fi

Keywords: safety, autonomous, mobile machine

Background

Automated functions and autonomy are increasing in mobile machines. The levels of driving automation for road vehicles are described in SAE J3016_201806 (2018). The levels are: No Automation (0), Driver Assistance (1), Partial Automation (2), Conditional Automation (3), High Automation (4) and Full Automation (5). Currently some cars have reached level 4, but level 5 (autonomy) in traffic environment is in research phase.

Driverless cars have been leading the development of autonomous ground vehicles due to enormous amount of research. Driverless cars have been driving autonomously millions of documented kilometers and there are some results available of the development so far. The year 2016 was a turning point in terms of risks of self-driving cars (Taeihagh and Lim 2019). During 2015, there were only about 20 minor accidents and in each them fault was attributed to human divers. In 2016, there was an accident that was obviously caused by a self-driving car. A little bit later, the first fatal accident happened. In most of the driverless car accidents, driver of a conventional vehicle hits the rear end of the driverless car within or close to an intersection. Taeihagh and Lim (2019) present that human is responsible for 90 % of all car accidents. One factor in accidents is that manual control of the autonomous vehicle is used to handle difficult situations. For example, Google (Waymo) driverless cars have had about 0,68 disengagements (i.e. manual driving required) per 1000 km (Dixit et. al. 2016).

In manual machines, humans have the main responsibility for safety. When the level of automation increases, liability turns more and more from human to automation. A currently unsolved question is whether automation can have better situational awareness and ability to control actions than a human driver. One factor here is that implementation of automation and safety functions requires many different technologies, like communication, navigation and perception systems. Failure of the safety ensuring technology is a risk source. Although safety systems make autonomous mobile machines safer, parts of the safety system can be also potential risk sources.

Aims

The aim of the study has been to identify and categorize safety risk sources and hazards related to autonomous mobile machines applied in industrial outdoors environments.

Materials and methods

The study included an analysis of standards for autonomous machinery, a literature review and a compilation of findings from recent projects conducted in VTT. Data related to driverless cars and manual mobile machines have been used as a benchmark for risk source identification.

Results

An important difference between driverless cars and autonomous mobile machines operating outdoors is that the operating area is usually isolated. Good examples of autonomous mobile machine systems are in mines and ports. Risks are minimized by preventing untagged persons (without tracking device) and manually driven vehicles from entering the area where the automated machines are operating in autonomous mode. Usually, automated machines are stopped and turned to manual mode when a person enters the area. The overall operating area of autonomous machines can have one or several area access control systems to monitor access to each critical part of the autonomous operating area. The safety of autonomous mobile machines is based on many kinds of safety measures (layers), such as fences, gates, access control systems, communication with fleet control and on-board sensors. One specific risk source of autonomous vehicles is related to perception systems. Outdoor perception sensors are not capable to operate in all environmental conditions. The sensors cannot usually detect objects, which are beside or behind another larger object. Long detection range and wobbling of the machine cause higher tolerances to the detection compared to indoors applications.
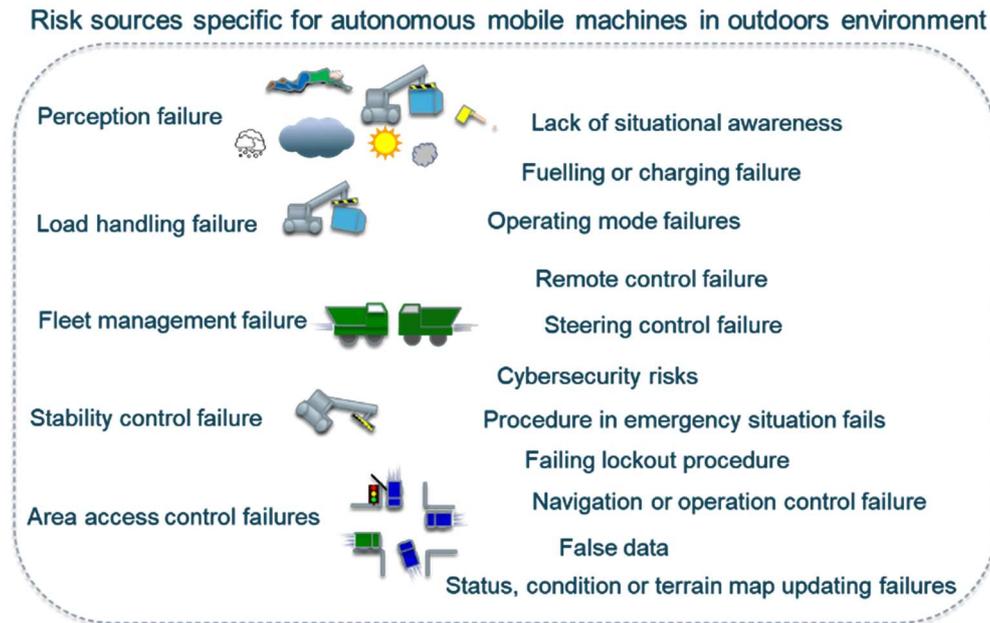

Fig. 1 Risk sources specific for autonomous mobile machines.

Another specific risk source of autonomous mobile machines is related to communication with area access control systems, fleet management systems and internal systems. Fig.1 shows an overview of risk sources.

VTT has made a checklist to identify risk sources specific for autonomous mobile machines. The checklist does not describe the risks in detail, but it is intended to cover subsystems, but not all components.

Conclusions

There are many kinds of different applications and new technologies are developed continuously. Therefore, risk sources for all kinds of autonomous mobile applications cannot be presented. The checklist gives ideas for risk assessment to identify new risk sources.

Acknowledgements

References

SAE J3016_201806. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. 2018.

Taeihagh, A & Lim, H. S. M, (2019) Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks, Transport Reviews, 39:1, 103-128, DOI: 10.1080/01441647.2018.1494640.

Dixit, V. V., Chand, S., Nair, D. J. 2016. Autonomous Vehicles: Disengagements, Accidents and Reaction Times. PLoS ONE 11(12): e0168054. doi:10.1371/journal.pone.0168054

Aarne Klemetti* and Erkki Räsänen

Foundations and Case Studies on the Scalable Intelligence in AIoT Domains

Abstract: The Internet-of-Things (IoT) concept is based on networked, mobile, and sensor equipped microelectronic devices. The deployment of artificial intelligence (AI) to IoT, referred to as artificial intelligence of things (AIoT), enables intelligent behavior for the whole cyber-physical system (CPS) whether it is designed for human co-operation, completely autonomous operations, or something in between.

The foundation of AI requires a lot of processing power due to the amount of data and recursive/concurrent nature of calculation. Until recently this has been accomplished mainly in the cloud environment, where the raw data is uploaded into. This exposes all the data, even private and sensitive data, to the transmission phase and processing system. In conjunction with IoT there is a possibility to perform ML closer to the origin of data concerning local intelligence. It means that only the results of local or edge ML are transmitted to cloud for more general aggregation of AI. Local systems do not need to send the raw data anymore, which helps on prevailing the privacy and security of the data. This type of ML is referred to as federated/collaborative learning (FL).

This study focuses on finding the existing and/or recommended solutions for up-to-date AI close to the devices. At first, the definitions of devices are reviewed in order to find out classifications of their capacity to contribute for the computation and scalability. Secondly, the other computing and serving options between the devices and the cloud are studied. Thirdly, the facts learned are being applied in two use cases in order to support the discussion and applicability of AIoT in practice.

The main conclusion is that there are no silver bullets for solving all the requirements. Instead, there are multiple options from mutually connected devices via middle layer support to cloud services, and distributed learning, respectively.

Keywords: Internet of Things, Machine Learning, Artificial Intelligence, Artificial Intelligence of Things, Federated Learning, Edge computing, Scalability

*Corresponding Author: Aarne Klemetti, Finland, Metropolia University of Applied Sciences, School of ICT, E-mail: aarne.klemetti@metropolia.fi

Second Author: Erkki Räsänen, Finland, Metropolia University of Applied Sciences, School of Smart and Clean Solutions, E-mail: erkki.rasanen@metropolia.fi

Background and aims: The main focus of this article is in the AIoT provided by edge computing. The research problem is that when, where, how, and why to implement on-premises AI-related computing with mobile - or more specifically portable - computing equipment. Our two research questions are:

1. Which are the key properties and requirements to IoT edge computing?

2. How to maintain the speed, reliability, safety, and security in AIoT computing?

Methods applied: We'll begin with a literature review on the latest research around AIoT and related areas. Then we approach the practicalities required with two use cases: an example on mining and another on setting up a test platform with remote building control and surveillance as practical applications.

Results: The amount of information available on AIoT shows that the topic is interesting from the viewpoint of scientific research. The selections we made on literature review support our RQs. In our view a more indepth survey on scientific papers should be conducted separately. This should be carried out from the viewpoints of benchmarking, testing, authorization, trust, and security of AIoT related concepts and applicable practices in general.

Conclusions: Our two research questions on the requirements were answered, but they need to be elaborated in every new implementation. We recommend also setting up customized environments for testing the systems. AI is a wide discipline with multiple possibilities. For edge purposes the techniques like federated learning is a good starting point.

It is important to understand also that the technologies

----

are evolving rapidly. The consequence is that the devices, hardware and software are not upgraded and developed synchronously. With that in mind the working systems tend to be version dependent until they are fully matured to production scale operations. There is still a lot of work to be done before the AIoT is business as usual. One should not wait, though, because there are so many disciplines involved and steep learning curves around. More importantly, one shouldn't expect to find silver bullets resolving the challenges.

Hoang Khac Nguyen*, Amin Modabberian, Kai Zenger, Xiaoguo Storm, and Jari Hyvönen

Model predictive control in multiple injection strategy for maritime diesel engines

Keywords: Model predictive control, multiple injection, diesel engine

---

*Corresponding Author: Hoang Khac Nguyen: Aalto University, Department of Electrical Engineering and Automation, E-mail: hoang.kh.nguyen@aalto.fi
Amin Modabberian: Aalto University, Department of Electrical Engineering and Automation, E-mail: amin.modabberian@aalto.fi
Kai Zenger: Aalto University, Department of Electrical Engineering and Automation, E-mail: Kai.Zenger@aalto.fi
Xiaoguo Storm: University of Vaasa, School of Technology and Innovations, Energy Technology, E-mail: xxue@uwasa.fi
Jari Hyvönen: Wärtsilä, Research and Development, Internal Combustion Engines, E-mail: jari.hyvonen@wartsila.com

Extended abstract

International emission regulations (e.g. Tier III, China II) are becoming stricter every year, which sets more challenges on the heavy duty, maritime engine manufacturers in particular. The amount of both cargo and passenger shipping is increasing rapidly. Because of the large energy efficiency needed in large ships no replacement of combustion engines can be foreseen in the near future. There is a need for new efficient use of renewable fuels and new low temperature combustion technologies that would reduce the harmful emissions. In 2020 the European Parliament has decided to include shipping in the emissions trading system (ETS), which will require a 40 percent reduction in carbon dioxide (CO2) emissions by 2030. In addition, reduction of sulphur, nitrogen dioxide (NO2) and small particle (PM) emissions are a strict requirement for the increasing amount of ships worldwide.

Lowering the emissions excessively under the legislation limits would increase the engine operating costs such as higher fuel consumption [1]. The challenge is to fulfill the emission standards and to maximize the engine efficiency. Overcoming this problem requires more advanced combustion control than the traditional engine tuning and calibration. There have been several new approaches in the engine combustion control, which are based on new low temperature combustion technologies, e.g. RCCI (reactivity controlled compression ignition), HCCI (homogeneous charge compression ignition) and PPC (partially premixed combustion). Control in these is complicated however, and they are based on controlling the cylinder pressure by several successive fuel injections during each engine cycle. Engine efficiency can be increased by maintaining the cylinder pressure at its highest level throughout the combustion [2]. Multiple injection strategy is one of the new methods being used to maximize the cylinder pressure. It is an alternative approach to single injection combustion, which has been proved to be more efficient in terms of noise and emission reduction, and fuel consumption [3]. The multiple injection enables better control of the fuel distribution [4].

In this work, a model predictive control (MPC) is applied for multiple injection strategy in a maritime diesel engine. The aim is to predict and control the engine combustion parameters cycle-to-cycle. The MPC controller is designed based on a state-space representation of the combustion process. The state-space is obtained by data driven method from a multiple injection combustion model.

The controller is then simulated on the developed multiple injection combustion model. Figure 1 demonstrates the simulation scheme.
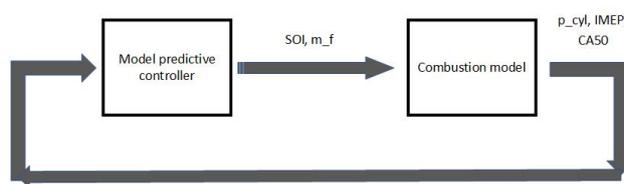

Fig. 1. A block diagram of the major inputs and outputs of the system.

The combustion model block simulates the engine combustion process based on the values of Start of Injection (SoI) of each individual fuel injection and injected Mass flow (m_f). The simulation calculates the values of engine's outputs such as maximum cylinder pressure (p_{cyl}) and Indicated Mean Effective Pressure ($IMEP$).

The reason for choosing the MPC method is upon its ability to solve the optimization problem using a moving time horizon window [5], which can be considered as the working cycle of the cylinder. In this problem, the MPC is controlling the fuel injection parameters under constraints such as the maximum cylinder pressure value. The optimization problem is to maximize the cylinder pressure and the IMEP over a cycle.

The developed control algorithm will be tested first by simplified combustion models, further by an extensive "true" model of a 4-cylinder test engine and finally by a real engine at the VEBIC laboratory in Vaasa.

Results of this work can be further used in real engine implementation and attached to more accurate engine models.

References

[1] Hoang Nguyen Khac, Kai Zenger, Xiaoguo Storm, Jari Hyvönen, et al. Operational profile based optimization method for maritime diesel engines. *Energies*, 13(10):1–21, 2020.

[2] Gabriel Turesson. *Model-Based Optimization of Combustion-Engine Control*. PhD thesis, Lund University, 06 2018.

[3] Yudai Yamasaki, Ryosuke Ikemura, Motoki Takahashi, Fumiya Shimizu, and Shigehiko Kaneko. Simple combustion model for a diesel engine with multiple fuel injections. *International Journal of Engine Research*, 20(2):167–180, 2019.

[4] Sylvain Mendez and Benoist Thirouard. Using multiple injection strategies in diesel combustion: Potential to improve emissions, noise and fuel economy trade-off in low cr engines. *SAE Int. J. Fuels Lubr.*, 1:662–674, 04 2008.

[5] Liuping Wang. *Model predictive control system design and implementation using MATLAB®*. Springer Science & Business Media, 2009.

Helena Leppäkoski*, Bishwo Adhikari, Leevi Raivio, and Risto Ritala

Prediction of future paths of mobile objects using path library

Abstract: In situational awareness, the ability to make predictions about the near future situation in the area under surveillance is often as essential as being aware about current situation. We introduce a privacy-preserving instance-based prediction method, where a path library is collected by learning earlier paths of mobile objects in the area of surveillance. The input to the prediction is the most recent coordinates of the objects in the scene. Based on similarity to short segments of currently tracked paths, a relative weight is associated with each path in the library. Future paths are predicted by computing the weighted average of the library paths. We demonstrate the operation of a situational awareness system where privacy-preserving data is extracted from an inexpensive computer vision which consists of a camera-equipped Raspberry PI-based edge device that runs deep neural network-based object detection and feature extraction algorithms on the camera feed and stores only the coordinates and timestamps of the detected objects. To infer which detections from different time instances came from the same object, we used probabilistic reasoning based on joint probabilistic data association, Hungarian algorithm and Kalman filter.

Keywords: Path Prediction, People Tracking, Probabilistic Data Association, Instance-based Learning, Computer Vision

——
*Corresponding Author: Helena Leppäkoski: Tampere University, Finland, E-mail: helena.leppakoski@tuni.fi
Bishwo Adhikari: Tampere University, Finland, E-mail: bishwo.adhikari@tuni.fi@tuni.fi
Leevi Raivio: Tampere University, Finland, E-mail: leevi.raivio@tuni.fi
Risto Ritala: Tampere University, Finland, E-mail: risto.ritala@tuni.fi

1 Extended abstract

Background: The current developments in camera technologies and deep-learning based signal processing have made computer vision systems cost-effective and feasible options for various surveillance tasks. In many applications, the ability to make predictions about the near future situation in the area under surveillance is as essential as being aware about current situation. For example, the security of the working environment of mobile machinery could be improved by a vision system that automatically detects objects in the area, predicts locations of the mobile objects, and determines how probably some parts of the area will be occupied in the near future.

We introduce a instance-based prediction method, where a path library is collected by learning earlier paths of mobile objects in the area of surveillance, and which preserves privacy of the tracked people. Many existing computer vision systems for surveillance rely on transmitting or storing video data to servers for further analysis. This compromises the personal privacy of the people in the area. In our method, only position coordinates of the detected moving objects and the detection timestamps need to be extracted from the camera data. Any data that might identify the individuals is not stored.

Aims: We demonstrate the operation of a situational awareness system that uses only privacy-preserving data extracted from the computer vision system to track paths, learn the path library, and predict paths with the path library. Our system uses the limited set of data to answer the following questions: Where there are people in the surveillance area? What kind of paths are they taking? Where will they be located, and which parts of the area will probably be occupied in the near future?

Materials and Methods: The structure of the path prediction system is shown in Fig. 1. In real data demonstration, we used the location and timestamp
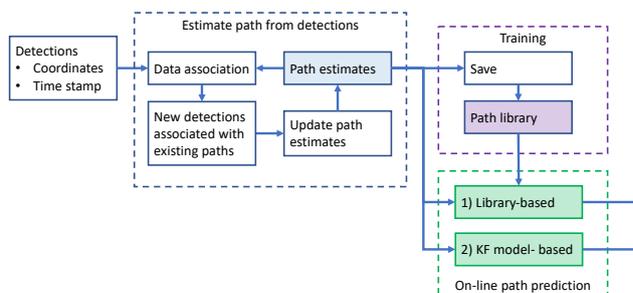

Fig. 1. Main functional blocks of the path prediction system.

Fig. 2. Camera view from the test setup running real time object detection on a Raspberry Pi platform.

Fig. 4. The predicted path is the weighted sum of the most similar library paths.

data recorded by a detection system, which consists of a Raspberry Pi 3b computer equipped with Pi camera module. The device runs single-stage detection (SSD) network with a MobileNet feature extractor. The system runs this object detection model on camera feed in real-time and saves the detection result. The data was collected with the camera looking over the open space of Tampere University Hervanta campus (Fig. 2).

To create the path library, we used stored location and timestamp data that was collected on one day during 13 hours. The data from the next day was used to compare the predictions produced by the path library and the traditional Kalman filter (KF). The path tracking and prediction was implemented with Matlab.

As the data did not include elements that link the latest detections to the earlier detections from the same object, we formed the link computationally using probabilistic reasoning (Fig. 3). We implemented the reasoning using Joint Probabilistic Data Association (JPDA), a well-known method in, e.g., radar-based surveillance systems. In JPDA, we used KF to propagate the estimates in time, Hungarian algorithm to associate the new detections to the existing path estimates, and again KF to update the corresponding path estimates with the new samples associated with them. In the KF, we used a motion model with position and velocity states, driven by zero-mean, Gaussian acceleration.
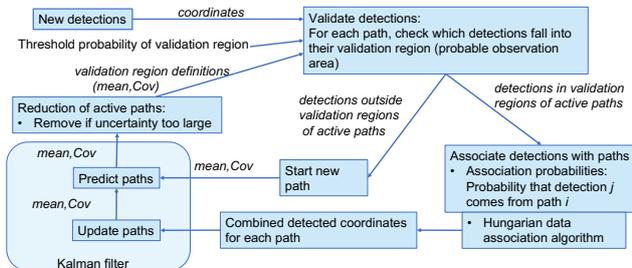
The input to library-based prediction is the most recent coordinates of the objects in the scene (Fig. 4). The paths are tracked from the detections with KF and JPDA techniques. When the lengths of such paths increase above a given threshold, the obtained path segment is compared to the contents of the path library. Based on similarity, a relative weight is associated with each path in the library. The future path is predicted by computing the weighted average of the paths in the library and its uncertainty is expressed with its weighted covariance matrix. Quite commonly, the prediction is composed of several "branches", meaning that the distribution of predicted agent's location is multimodal. In this case an appropriate descriptor of the uncertainty is the smoothed probability distribution produced by the Gaussian mixture that represents the branches.

Results, Conclusions: The predictions based on path library were compared to KF predictions. Examples of path tracking and prediction and area occupancy prediction show that the path library gives much more accurate, but multimodal predictions (Figs. 5, 6).
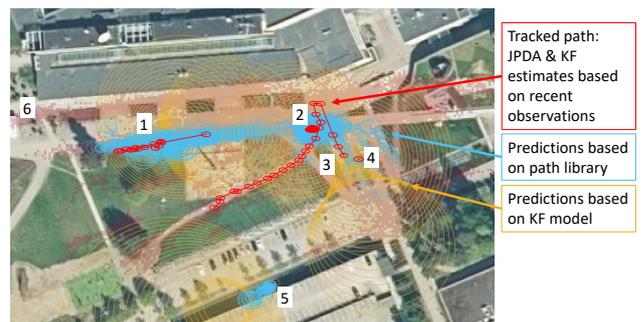

Fig. 5. Real data example: path tracking and predictions with Kalman filter and path library.

Fig. 3. Subtasks of probabilistic reasoning for path estimation.
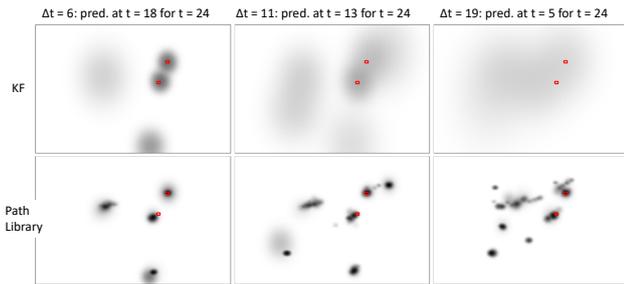
Fig. 6. Real data example: comparing area occupancy predictions by Kalman filter (top) and path library (bottom). The red markers give the locations of objects at t = 24 s. The gray clouds indicate the predicted probability of the location being occupied by the agent. The predictions were made using observations obtained 6 s (left), 11 s (middle) and 19 s (right) earlier, respectively. The path library gives much more accurate, but multimodal predictions.

Extended Abstracts
ISBN: 13 978-952-5183-60-3

Automaatiopäivät24 2021

Teijo Juntunen* and Risto Ritala

Comparing Performance of Algorithmic and Driver-Planned Routing of Forest Forwarder

Abstract: The time and energy efficiency when collecting felled wood logs from a forest stand are critical for the forestry economics and sustainability. Choice of collection routes varies greatly depending on the experience of the forest forwarder driver. With modern vehicle routing optimization algorithms, this variance could be reduced, and less experienced drivers supported, therefore making the log collection at forest stands more efficient. In this paper the repeated matching (RM) algorithm solving the routing problem for a capacity-limited forwarder is adapted from an earlier work and extended to consider constraints on the number route segments can be driven through and one-way route segments. Furthermore, the forwarder unloading to sorted piles is integrated to the route optimization. The performance of the algorithm is compared to that of a group of forwarder driver students in Finnish national skill competition finals. The case had 164 piles of six timber classes and three depots, some unidirectional segments and some segments with limited number of drives. When our algorithm was run for 8 hours, it performed best amongst the nine finalists, and when it was run for one hour, it performed fourth best.

Keywords: RVRP, CVRP, repeated matching, realistic constraints, metaheuristic

*Corresponding Author: Teijo Juntunen: Tampere University, Finland, E-mail: teijo.juntunen@tuni.fi

Risto Ritala: Tampere University Finland, E-mail: risto.ritala@tuni.fi

1 Extended abstract

Background and Aims: While the harvester travels through the forest felling trees next to its driving route, a route network is created in the felling area. As the harvester is working, a map is created from harvesters GPS data. Using this map, a forwarder driver plans his collection routes. The experience of the forwarder driver is the most important factor in the productivity of the resulting route set. Unnecessary driving also strains the soil and trees that were left standing by the harvester. For these reasons, the aim of this paper is to investigate how well the route optimization algorithm created route sets compare to the route choices of human drivers and whether the performance of inexperienced drivers could be improved by providing them with ready-made driving routes designed by the algorithm.

Previously, this CVRP path optimization problem has been investigated in a study by Flisberg et al. [1], using the repeated matching method. Our work includes real-world constraints that significantly impair the algorithm's efficiency: some routes are marked as one-way only (e.g. a steep slope) and some routes can be travelled through only a limited number of times before they are worn out. Costs depending on the direction of travel (reversing being slower) and cost depending on the mass of the load were included. The capacity constraints and wood grade specific unloading areas in the Flisberg et al study were also included in our study.

Methods and materials: The algorithm first calculates the cost matrix, i.e. the shortest distances by the Dijkstra algorithm for all piles and unloading area intersections. The adjacency matrix is calculated, i.e. which of the collection piles are adjacent to one another. Because of the one-way routes, adjacent matrix is not symmetric. The route set that collects all the piles is then solved with the repeated matching method (Flisberg et al.), which creates a perfect matching of piles that includes every pile once and only once. A total cost of this route set is then calculated according to the cost structure. The internal order of the piles in each route is optimized by a genetic algorithm. The flow chart of the algorithm is seen in figure 1.
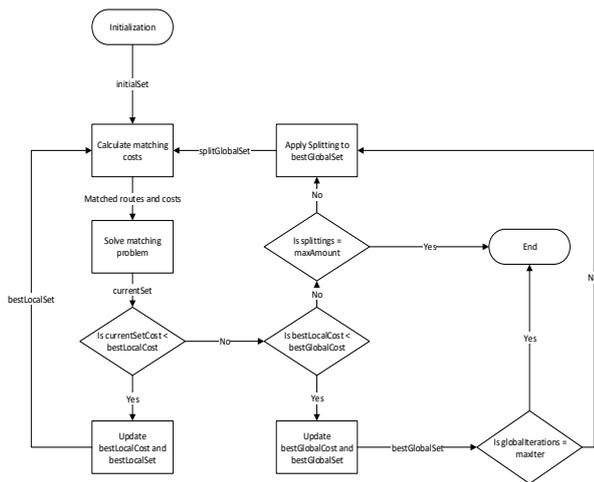

Fig 1. A diagram of the repeated matching algorithm used in this study.

In the Taitaja2014 competition finals, nine forest machine driver students designed and implemented driving routes at Ponsse Forwarder Game (PFG), trying to maximize productivity by minimizing their driving time. PFG is a game that simulates a real driving situation with the same restrictions as the algorithm used. The productivity of the solutions of the algorithm was compared with the results gathered from the performance of the human driver students. There were four one-way routes on the map and two route segments were limited to two drives. There were 164 piles to be collected and 6 grades of wood. All piles were one cubic meter in volume and consisted of a single wood grade.

The search space is too large to solve the optimal route set, but the solution improves as a function of the computational time used. In this study, one-hour, two-hour, and eight-hour computation times were applied, of which an hour-long calculation time would be useful even in a real-life situation where the calculation would be performed immediately after the harvester has completed the roadmap. In many cases the route set could be optimized during the night.

Results and conclusions: In total 50 instances of one-hour optimizations were made, of which the best, worst, and four middle solutions are shown in Table 1.

Table 1. Six results taken from 1-hour calculations that were driven in PFG:

Set #	Cost units	Productivity, m3/h
1	17031	26.5
24	18749	24.6
25	18802	24.0
26	18838	25.1
27	18851	24.2

50	20234	23.8

The average results of the 8-hour, 2-hour and hourly solutions compared to the results of the human drivers in the Taitaja computation are shown in Table 2 (when five 8-hour, 20 2-hour and 50 hourly solutions were considered). In addition to total productivity, the productivities during driving empty, loading, driving loaded and unloading are specified in the article.

Table 2. Productivity results of the Taitaja2014-competition compared with the algorithm.

Driver	Productivity, m³/h
Driver #2	27.9
Driver #9	26.1
Driver #3	26
Driver #7	24.6
Driver #1	24.6
Driver #8	23.6
Driver #5	23.2
Driver #6	22.6
Driver #4	22.2
Algorithm (8 h)	28.0
Algorithm (2 h)	26.1
Algorithm (1 h)	24.6

The hour-long solutions are comparable to the average solution time of human driver students while 2-hour calculation solutions perform close to the top of the drivers. Long 8-hour calculations perform at the same level as the top finalist in this competition.

Reference:

[1] P. Flisberg, M. Forsberg ja M. Rönnqvist, "Optimization Based Planning Tools for Routing of Forwarders at Harvest Areas," *Canadian Journal of Forest Research,* 37, (11), pp. 2153 - 2163, 2007.

David Hästbacka*, Jari Halme, Heikki Mesiä, Mikael Björkbom, Rupesh More, Antti Jaatinen, Henrikki Hoikka, Laurentiu Barna, Jyrki Keskinen, Marko Elo, and Henri Pettinen

Developing data-driven operational and analytical services for interoperable industrial ecosystems

Abstract: Industrial production systems need data for their operations as well as for value-added services, such as condition monitoring and maintenance. When developing and applying new technologies one challenge is combining and integrating data and services efficiently. This paper gives a brief overview of two use cases in the Productive4.0 project and the main means implemented that improve use of data and developing analytics solutions using a unifying service architecture. The use cases are production monitoring of chain hoists and condition monitoring of vibrating screens.

Keywords: Production monitoring, Condition monitoring, Systems of systems, Interoperability

*Corresponding Author: David Hästbacka: Tampere University, david.hastbacka@tuni.fi
Jari Halme: VTT Technical Research Centre of Finland, jari.halme@vtt.fi
Heikki Mesiä: Konecranes, heikki.mesia@konecranes.com
Mikael Björkbom: Konecranes, mikael.bjorkbom@konecranes.com
Rupesh More: Konecranes, rupesh.more@konecranes.com
Antti Jaatinen: Metso Outotec, antti.jaatinen@mogroup.com
Henrikki Hoikka: Metso Outotec, henrikki.hoikka@mogroup.com
Laurentiu Barna: Wapice, laurentiu.barna@wapice.com
Jyrki Keskinen: Wapice, jyrki.keskinen@wapice.com
Marko Elo: CrossControl, marko.elo@crosscontrol.com
Henri Pettinen: CrossControl, henri.pettinen@crosscontrol.com

1 Introduction

Process and equipment data is needed both for production as well as for value-added services, such as condition monitoring and maintenance [1]. In modern systems, sensors provide a lot of data but, increasingly, other systems as well. Also, machine or device fleets can provide more insight, extending the connection between utilizers and manufacturers.

The challenge is developing and applying new technologies, and combining and integrating data and service components efficiently and interoperably, i.e. in a plug and play fashion [2]. In order to develop modular components, e.g. for data acquisition, preprocessing and advanced analytics, this means that data and its semantics are interoperable, communication is standardized, and agreed means to compose functionality are in place. Further on, information security is essential as systems also span open networks possibly including multiple other vendors. Finally, as production related systems span the whole range of IoT, edge, fog and cloud infrastructures they need to cope on a wide range of hardware and software platforms.

Productive4.0 is a large European project under the Digitalizing European Industry initiative with the focus on common integration principles for IoT and systems of systems. It is funded by EC ECSEL and national funding agencies of the member states such as Business Finland. The project involved over 100 partners across Europe during 2017-2020. One of the aims of such a huge project is involving industry, technology providers and research organizations to collectively develop and demonstrate new technologies and their application on a large scale. The outcomes are expected to contribute to standards for products, processes and business models that will enable the digitalization of industry.

The research and development in Finland, focusing on two use cases of production monitoring and condition monitoring, were carried out by Konecranes, Metso Minerals, Wapice, CrossControl, VTT and Tampere University [3][2].

2 Use cases and results

In the production monitoring use case, various IoT sensoring was mounted on a chain hoist used in a typical production assembly setting. The overall objective was to achieve intelligent activity monitoring for combined analytics with machine and other data. This would give visibility into equipment activity, performance and efficiency, and ultimately automation of material flows and task optimization. The needed data varies for different processes and the data collection solution implementa-

tion can be device specific. Therefore it would be beneficial if the system would enable independent and exchangeable software components and communication.

The second use case focused on condition monitoring of vibrating screens. These machines are used to separate materials such as ores and are thus prone to wear caused by the involved large masses and accelerations. The condition monitoring could be built by simply transferring all data to the cloud. However, the objective was to unify the analytics application composition and execute it similarly on the edge as well as in the cloud, independently of what kind of measurement setups or data processing tools are used.

Central to both use case solutions is the use of the Arrowhead Framework (AHF) [4] as a key interoperability component. AHF is an open source service framework offering the tools to discover, bind and authorize application service compositions following a system of systems (SoS) model [5]. The application composition follows the logic of systems providing services that are consumed by other systems. The services are predefined in terms of their interface and data semantics between the system of systems to be composed. To ensure wider application ecosystem interoperability AHF uses a predefined model for the run-time discovery, binding and authorization. This means that plug and play is achieved using a chain of trust and services are interchangeable as long as the consumer and provider understand each other. Several supporting services are also provided as part of AHF expanding its functionality.

Additional specification was needed for the application services, their interfaces and data payloads as AHF mainly provides the infrastructure for binding services. Service interfaces and message semantics were defined so that service providers could easily be exchanged. Due to the service nature this also enabled implementing the services using different implementation platforms.

As a result dynamic application service composition was achieved for both use cases meaning that the flow of data from sensors or sensor systems could be centrally orchestrated to specific storage or processing services at run-time. It was also showed that various hardware and software platforms can be supported given that web services are used as the interoperability layer.

Regarding service composition interoperability AHF provides the foundation for the application ecosystem in which to discover, bind and authorize compositions, and use services across different systems. For full technical interoperability it is further required to specify and agree on application service interfaces, their interaction patterns, and data semantics.

3 Conclusions

Production systems are expected to be even more networked in the future sharing data among individual devices and systems. This calls for new solutions that enable efficient development of applications integrating data and functionality from a wide range of involved systems. Dynamic composition and interoperability can be facilitated using common, shared framework models such as AHF. The development of these kind of harmonized frameworks and associated business models and ecosystems – enabling the full digitalization – require efforts in which technologies are jointly developed and piloted in industrially relevant environments.

Acknowledgement

References

[1] Burns T, Cosgrove J, Doyle F. A Review of Interoperability Standards for Industry 4.0. *Procedia Manufacturing*. 2019; 38:646–653. 29th International Conference on Flexible Automation and Intelligent Manufacturing, June 24-28, 2019, Limerick, Ireland, Beyond Industry 4.0: Industrial Advances, Engineering Education and Intelligent Manufacturing.

[2] Hästbacka D, Halme J, Larrañaga M, More R, Mesiä H, Björkbom M, Barna L, Pettinen H, Elo M, Jaatinen A, Hoikka H. Dynamic and Flexible Data Acquisition and Data Analytics System Software Architecture. In: *2019 IEEE SENSORS*. 2019; pp. 1–4.

[3] Halme J, Jantunen E, Hästbacka D, Hegedűs C, Varga P, Björkbom M, Mesiä H, More R, Jaatinen A, Barna L, Tuominen P, Pettinen H, Elo M, Larrañaga M. Monitoring of Production Processes and the Condition of the Production Equipment through the Internet. In: *2019 6th International Conference on Control, Decision and Information Technologies (CoDIT)*. 2019; pp. 1295–1300.

[4] Delsing J, Eliasson J, van Deventer J, Derhamy H, Varga P. Enabling IoT automation using local clouds. In: *2016 IEEE 3rd World Forum on Internet of Things (WF-IoT)*. 2016; pp. 502–507.

[5] Derhamy H, Eliasson J, Delsing J. System of System Composition Based on Decentralized Service-Oriented Architecture. *IEEE Systems Journal*. 2019;13(4):3675–3686.

Esko K. Juuso

Intelligent temporal analysis of coronavirus statistical data

Esko K. Juuso, Control Engineering, Environmental and Chemical Engineering, Faculty of Technology, P.O.Box 4300, FI-90014 University of Oulu, Finland, E-mail: esko.juuso@oulu.fi

1 Background

The coronavirus COVID-19 is affecting around the world. There are strong differences between countries and regions. People of all ages can be infected but older people and people with pre-existing medical conditions are more vulnerable to becoming severely ill.

The risk is presented with three parameters:
– Transmission Rate (Ro) - number of newly infected people,
– Case Fatality Rate (CFR) - percent of cases that result in death,
– Determine whether asymptomatic transmission is possible.

Fluctuations, trends and models have been used in temporal analysis for all types of measurements, features and indices. Recursive updates of the parameters are needed in prognostics.

2 Aims

This research aims to develop unified intelligent temporal analysis methodologies for detecting the fluctuations, trends and severity of the corona situations. Parametric systems are used to adapt the solution for varying operating conditions caused by local areas and groups of people. Recursive updates are used in the parametric models.

3 Materials and methods

Generalized norms are used in data analysis to extract features from waveform signals collected from the statistical databases. The computation of the norms can be divided into the computation of equal sized sub-blocks, i.e. the norm for several samples can be obtained as the norm for the norms of individual samples. This means that norms can be recursively updated.

The analysis is done for several groups of people. Within each group, the risk levels are represented by using nonlinear scaling. The scaling functions are defined by five corner points by generalized norms whose orders are obtained from the data. These orders are used in the recursive tuning. Fluctuations are detected are detected from difference of two norms related very high and low order, correspondingly.

The calculations are done with numerical values and the results are represented in natural language. Trend indices are calculated from scaled values for informative short and long time periods. The trend index and its derivative visualize trend episodes. The severity of the situation is evaluated by a deviation index which combines the trend index, the derivative of it and the level.

The analysis is done in a similar way for different subsets. Specific scaling functions can be used in local analysis and for people groups to increase the sensitivity of the temporal analysis. More aggregated material is used for analyzing countries and continents.

The norms can be recursively updated and the norm orders related to the scaling functions are updated less frequently.

4 Results

Different trend episodes are detected efficiently and the need for the recursive tuning is clear during the autumn period. The time periods, thresholds and weight factors are selected in the tuning.

5 Conclusions and future development

This research is done for selected datasets and future development focuses on comparing different subsets and integrating the calculation levels.

Esko K. Juuso

An advanced teaching scheme for remote problem-based learning

Esko K. Juuso, Control Engineering, Environmental and Chemical Engineering, Faculty of Technology, P.O.Box 4300, FI-90014 University of Oulu, Finland, E-mail: esko.juuso@oulu.fi

1 Background

Engineering education needs to provide both theoretical knowledge and problem-solving skills. A traditional organization of the courses gives separate lectures and practical sessions. Lecturing is not the best possible method in reaching the goals mentioned above. Computer exercises are good tools in teaching the skills. However, this approach would require extensive time to cover the curriculum. Learning by doing is very efficient when it is combined with lectures to provide additional material and perspectives.

An advanced teaching scheme, which aimed to balance these goals by combining different teaching practices, was presented in [1]. The teaching scheme combines lectures, computer exercises, case studies, seminars and reports. Problem-based learning is the key and the teachers act as project managers facilitate the learning process. The scheme has been found to be beneficial for overall learning progress and the students are increasingly ready to use the course material in practice.

Currently, the teaching periods at the universities are carried out remotely. This practice was already started in the spring 2020 and it will continue for many months. Learning management systems provide essential support for remote teaching. Systems developed for virtual meetings, webinars and conferences bring new tools for teaching as well. Lectures are widely done with these tools and exercises can be done remotely and reported through learning management systems. However, interactive working practices require additional efforts.

2 Aims

This research aims for adapting the advanced teaching scheme to the new period of remote teaching practices.

3 Materials and methods

Lectures, which are aimed for giving the overall ideas and extending the problem-based learning, can be done by remote lectures. Lecture questions are aimed for activating student questions and interaction.

Individual instructions in the exercises are needed for getting all students more closely in the same level. The problem-based case studies deepen the learning.

In the advanced teaching scheme, the seminars including student presentation and opponent questions are aimed for integrating the different topics into a flexible toolbox.

4 Results

Participating in the remote lectures are preferred and the lecture questions should be available during the lectures. The presentations should be divided into two or preferably three subtopics with a discussion period between. This is important when the presentations are available after the remote lectures. Too long lectures do not activate questions and the lectures without questions will also reduce the lecture participation.

The seminars including presentations, opponent tasks and discussions are important in completing the sufficient material for the continuous assessment. Concluding remarks given by the teacher provide motivating material for the students. The final reports are very informative for the evaluation of the learning. A fair grading can be achieved by weighting the assessments of the different parts. The exams, which are difficult to organize properly, are not needed.

5 Conclusions and future development

The advanced teaching scheme can be adapted in the remote teaching. The continuous assessment combines all the parts of the learning results.

References

[1] E. K. Juuso. An advanced teaching scheme for integrating problem-based learning in control education. Open Engineering, 8(1):41–49, 2018. doi: 10.1515/eng-2018-0006.