Application

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Information about application

Call name: Forskningsbidrag Stora utlysningen 2015 (Naturvetenskap och teknikvetenskap)

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Descriptive data

Project info

Project title (Swedish)*

Modellering av tillit i kooperativa intelligenta transportsystem

Project title (English)*

Modeling of trust in cooperative intelligent transportation systems

Abstract (English)*

Trusting shared information always implicate a risk, buying something used, having conversations over the Internet or relating to rumors are all examples from our daily life, when we with or without consiousness, handle these risks. In lieu of the development of fast connectivity and high focus on technologies for high speed communication this project will develop methods that will facilitate the usability of shared information. Within the transportation system, standards for sharing information are introduced to facilitate development and deployment of cooperative systems. Sharing of information will enhance the safety, throughput and comfort in the transportation system by improving the awareness of the road-users. Although safe and reliable communication is assured, the individual road-users need to be able to trust other road-users and their information - both in a smart urban intersection without traffic light control and on the motorway while driving at high speed with short intervehicular distance. This becomes crusial as vehicles become more and more automated. If vehicles only trust their own sensors they will not reach their full potential, the major benefit of automated vehicles comes when they also make use of shared, cooperative, information.

Within the transportation system where vehicles connect to each other ad hoc without a centralized authentication and authorization server that handles security an alternative where vehicles themselves establishes mutual trust is required.

This work will explore and develop data mining methods based on random forests to build rational computational trust for cooperative intelligent transportation systems. During the project, demonstration use-cases will be identified, response and predictor variables for the trust model will be identified and a simulation model will be created to generate the data. The main part of the project is to explore real-time data mining to prepare the available data for the trust models and to further our understading about random forests, its proximity matrix and how it can be used to facilitate dicision making within cooperative systems by providing a trust model of the surrounding vehicles.

The expected results from this project are:

* Characterized and structured data from Vehicular Ad Hoc Networks (VANETs) prepared for real-time data mining
* Extended knowledge about random forests and its proximity matrix
* Data mining methods based on random forests taking into account the fast changing and heterogenous data from VANETs
* Models that describe trust between the road users within the cooperative intelligent transportation system

The project will run for four years from 2016-2019.

Popular scientific description (Swedish)*

Att lita på information innebär alltid en risk. När vi köper något (begagnat), läser något eller chattar på internet är exempel på vardagliga händelser där vi medvetet eller omedvetet hanterar denna risk. Inom den snabba utvecklingen av internet och av kommunikation där stort fokus ligger på att ständigt få högre bandbredd och kortare svarstider är det lätt att glömma värdet av informationen och vad den ska användas till. Inom transportsystemet har standarder utvecklats för att kunna dela information mellan trafikanter och mellan fordon. Att dela information ska förbättra säkerheten, effektiviteten och komforten genom att trafikanter får ett ökat medvetande om trafiksituationen. T.ex. kan infrastrukturen varna trafikanter om ett vägbygge eller om halka eller en ambulans kan skicka information om att den närmar sig för att kunna varna tidigare. Genom att följa kommunikationsstandarder kan informationen delas på ett säkert sätt men, vi vill ändå försäkra oss om att informationen går lita på. Om ett vanligt fordon felaktigt säger att det är en ambulans och vill ha fri väg betyder ju det att informatioen inte går att lita på - även om den kommer fram på ett säkert sätt. Genom att studera beteendet hos trafikanter och mäta och jämföra det observerade beteendet från olika informationskällor vill vi lära oss mer om tillit mellan trafikanter. Till exempel, om vi jämför både position och hastighet som mäts med radar och jämför med vad som skickas via kommunikation går det validera datakällorna. På liknande sätt går det använda en offentlig databas för att lokalisera var ambulanser befinner sig och jämföra dem med den information som tas emot via trödlös kommunikation. Vi vill använda informationen för att bygga modeller av tillit som kan användas av automatiserade fordon för att ta beslut. I dagens transportsystem blir fordon mer och mer intelligenta och automatiserade, men ett strikt autonomt fordon litar bara på sina egna sensorer - precis som en mänsklig förare som endast litar på sin syn och hörsel. Inte förrän fordonen börjar använda kommunikation, så att de kan se bortom horisonten och därmed agera tidigare, kan de dra nytta av sin intelligens och börja köra bättre än både människor och autonoma fordon.

Detta projekt kommer att utfroska data mining-metoder för att bygga tillit mellan trafikanter och fordon. Projektet kommer att identifiera vilka signaler som behövs och vilket beteende som karaktäriserar tillit. Huvuddelen av projektet kommer att studera realtidsanalys av data för att kunna bygga modeller av tillit. Slutmålet är att kunna utveckla automatiska fordonssystem som kan lita på varandra så att trafiksystemet ska kunna bli säkrare, effektivare och bekvämare att färdas i.

Project period

Number of project years*

4

Calculated project time*

2016-01-01 - 2019-12-31

Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

SCB-codes*

1. Naturvetenskap > 102. Data- och informationsvetenskap (Datateknik) > 10207. Datorseende och robotik (autonoma system)

2. Teknik > 202. Elektroteknik och elektronik > 20205. Signalbehandling

1. Naturvetenskap > 102. Data- och informationsvetenskap (Datateknik) > 10206. Datorteknik

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Enter a minimum of three, and up to five, short keywords that describe your project.

Keyword 1*

Data mining

Keyword 2*

Machine learning

Keyword 3*

Cooperative Intelligent Transportation Systems

Keyword 4

Vehicular Ad Hoc Networks

Keyword 5

Computational trust

Research plan

Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

Reporting of ethical considerations*

This work will be utilizing simulated data and neither animals, humans or any data therefrom will be used within the research project. Thus, no ethical questions will be handled within the project.

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

Research plan: Modeling of trust in cooperative intelligent transportation systems

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March 30, 2015

1 Purpose and aims

The purpose of the project is to further our knowledge about rational reputation and trust modelling within cooperative intelligent transport systems (C-ITS). Vehicles within C-ITS can on the one hand be autonomous units that use on-board sensors to assess the environment to be able to navigate towards their destination. In this setup they rely solely on their own sensors. On the other hand they can use wireless communication to interact with other vehicles. The overall goal of using communication and share information is to utilize the joint assessment of the environment to improve safety, throughput and efficiency. To utilize information from other vehicles for such goals the information needs to be trustworthy.

The aim of the project is to explore data-mining tools, especially random forests, to investigate the mechanisms within C-ITS that enable the establishment of reputation models of road users (agents). The mechanisms trigger trade-offs such as trust, integrity, reliability and security. The C-ITS network is a heterogeneous system with temporal relationships and the traffic behaviour is often characterized by local rules and manners affecting the mechanisms mentioned above. These features of the C-ITS network also motivates the need to have trust mechanisms distributed among the agents instead of being centralized. Given that secure communication is guaranteed, the aim is to model the reputation of the agents within the neighbourhood in order to create trust between these agents.

The research can be divided into two sub areas, *data extraction* and *data-mining*.

Research questions regarding data collection and extraction are:

- Can a reliable reputation and trust model be based on on-board sensors only?
- How should the V2X and on-board sensor data be combined to provide a more reliable trust model?
- Can inference and propagation within V2X communication be used to improve the establishment of a reputation and trust model that covers more agents and a larger neighbourhood?

The research tasks regarding the data-mining tools to be studied are:

- Investigate how the heterogeneous and temporal C-ITS data should be prepared to fit the data-mining tools e.g. real-time streaming data-mining to create data for reputation and trust modelling
- Explore how random forest can model behaviour of different agents
- Investigate how behaviour, reputation and trust are related to each other
- Elaborate upon how trust from different models may be combined
- Explore the trade-offs between computational cost, data size and dimension, tree configuration and the performance of the trust models

2 Survey of the field

C-ITS aims at improving the transport system with regard to safety, throughput and efficiency. Research around wireless communication and vehicular ad hoc networks (VANETs) has been a hot topic for a decade and recently ETSI and CEN released a communication standard for vehicular communication. The standard facilitate the industrial roll out of cooperative systems. However building safety critical applications based on sensor readings from neighbouring vehicles is not considered or accounted for in the standards. Developing this capacity will require methods that can provide predictable and reliable models of the neighbouring vehicles.

For humans, trust is achieved by predictability and reliability. For example, if a vehicle in front of me is driving with high speed variation and large lateral movements I am likely to keep a larger distance than if the vehicle is driving straight with steady speed. This project will develop computational methods that can model reputation by describing these attributes (behaviour) and that automatically can be interpreted and used by autonomous and cooperative vehicles to model their trust about their surrounding vehicles.

2.1 Computational trust and collaborative filtering

Trust is based on reputation and is often used to create mechanisms used to select with whom to interact with. However, inevitably question arise on vulnerability of such a mechanism since it also exposes a safety and security risk. Normally a trust model exploits data based on direct experiences, e.g. observations that are self-perceived by the decision maker. Another source of data is witness information from others, which in turn may be based on their own observations or even might be gathered from others. A third data source that involve social networks has also been reported as information for trust and reputation modelling [20, 16, 25, 13].

Our view of trust is inspired from collaborative filtering [21, 17] that is often used in recommender systems on the web. Such systems often use similarities between different users, based on their historical behaviour patterns, to recommend a new product, movie or music. Such systems are for example used by Amazon and Netflix. Collaborative filtering can be divided into two main categories, memory-based or model-based. Memory-based systems use typically

use stored historical data to predict new behaviour, k-NN [5] is the most used data-mining technique in this category. For the model-based systems, machine learning algorithms for regression or classification e.g. Neural Networks and Bayesian models are amongst the most common ones [21]. Also random forests has been used in recommender systems for e.g. movies [4].

A general challenge of recommender systems is data sparcity and to some extent this is relevant for the traffic application where vehicles normally meet temporary or rarely. The *cold start* problem, when new road-users appear in your network, will be a frequent challenge. In this work we will explore the possibility to use a general trust model (trained using historical data) until enough data is collected to establish a trust model for the current situation.

In [19] the authors come one step further in the recommendation process. They discuss that the similarity between users is not enough in a recommender system but also trustworthiness should be considered. In their paper they propose trust-based models where historical ratings are used as input. They also discuss two types of trust, context-specific interpersonal trust where a users has to trust another user and system / impersonal trust that describes how a user trusts a system [19]. In our work we focus on the latter and especially we will elaborate on using inference and propagation of the form $(A \Rightarrow B \Rightarrow C) \Rightarrow (A \Rightarrow C)$ where A, B, and C are agents with interpersonal trust. In [17] trust is further elaborated upon and defined as a network of interacting peers which is similar to the discussion in [19].

2.2 Vehicular Ad Hod Networks (VANETs)

Previous research within C-ITS and VANETs has focused on the establishment of a communication link and how to guarantee security and reliability. With those systems in place and the ever-growing connectivity, systems that also can make proper use of the shared data is required.

In our previous work on C-ITS and VANETs a partly self-driving vehicle was developed [14] that automatically was controlling the longitudinal speed whereas the lateral control was made by a human. In this previous work a sensor fusion algorithm, based on Kalman filtering [14], was used to weight the cooperative information (speed, acceleration and position) from other vehicles with the on-board sensor information (speed, acceleration, position, radar readings of distance to preceding vehicle) from the ego-vehicle, to create input for the longitudinal controller.

In this work we will develop data-mining methods that can describe the reputation of agents that in turn can be used to model reputation and assess trust within C-ITS applications.

The following chapters describe the project setup and the theoretical framework that will be used and developed. To our knowledge this is a novel approach to modelling of reputation and trust and has a large potential to speed up the introduction of C-ITS applications within the traffic system.

3 Project description

For the latest generation of vehicles, on-board sensors are used to improve the awareness of vehicles. For example an ultra sonic sensor provides a proximity

measure in parking assistant functions to facilitate parking, which gives satisfactory sensor readings and accuracy for low speed applications. However for high speed applications that are safety critical often at least two sensors are fused to give higher reliability, e.g. radar and camera or laser and camera are examples of combinations that are common in for example adaptive cruise control or automatic brake functions. Moreover, automated functions in the vehicle of the future can with the help of the developed algorithms from this project improve the awareness and thus safety as they receive, and more importantly will be able to, trust information from vehicles from further away than they are able to observe with their on-board sensors.

Within this project we will study how the on-board sensors can be used to build trust towards the observed vehicle by comparing the measured behaviour (using on-board sensors) with the behaviour observed using V2V communication. If trust is established, inference may be used in conjunction to witness information from the observed vehicle to also build a trust model of vehicles observed by another vehicles. In this way a chain of trust may be formed. However, such complex relationships between vehicles call for more knowledge to be able to build accurate and reliable models of reputation and trust. Fortunately, this is the focus of this project.

3.1 Data-mining

Knowledge about data can be gained by using data-mining which is used to extract implicit, interesting, and previously unknown information that may be hidden within large data sets [24, 26]. Both regression and classification methods are used in data-mining, typically to predict future behaviour in a process [10, 9] or to distinguish between different patterns or objects [7, 6]. Traditionally methods involving, Neural Networks [1], Support Vector Machines [22], k-NN [5], Classification and Regression Trees (CART) [3] and Self-Organizing Maps (SOM) [15] are amongst the most popular.

This project will investigate and develop data-mining methods and in particular the random forests, that are a type of CART, for building behaviour models (describing reputation). The ultimate goal is to use RF to develop computational trust that can be exploited by automated and cooperative vehicles to enhance the future traffic system.

Random forests (RF) are created by an ensemble of weak learners [2], and are used for both classification and regression problems [23, 6, 11]. Weak learners are characterized by low bias and high variance whose performance depends of the strength of the individual trees and on the dependence between them [2]. In a decision tree, at each node, a small group θ_k of m variables, (m between 1 and M, where M is the number of dimensions), is selected at random, and is used for splitting. To achieve low bias the trees are grown to full depth and the θ_k are independently and identically distributed (i.i.d.) that governs low correlation between the classifiers. Given the data set X^{NxM} where N is the number of samples and M is the number of dimensions, each tree in the RF is trained using a bootstrap sample set, where approximately one-third of the data is left out. By varying the number of variables used, different generalization performance may be achieved. Starting the search from $m = [\log_2(M) + 1]$ of $m = \sqrt{M}$ is often suggested [2]. The bootstrap samples are stored in a vector χ_k. For each tree k, the data that are not used for training, the out-of-bag (OOB) data, are

used to estimate e.g. the generalization performance, variable importance and proximity[2]. As more trees are added to the RF, the generalization performance will converge to a limiting value and there is no risk of over-fitting in the RF as the number of trees grows large [2], a general architecture of a random forest is found in Fig.1.

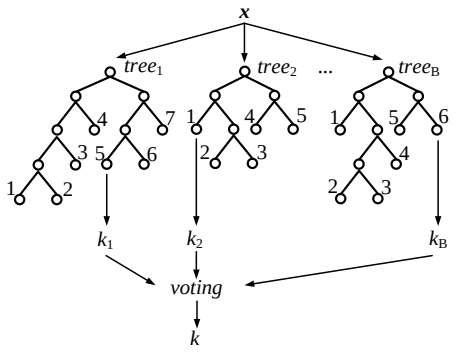

Figure 1: A general architecture of a random forest.

The project will initially investigate the models described in Fig. 2. Figure 2 illustrates three vehicles v_1, v_2, v_3 that receive V2V information w_{i+1} from (in this example) the vehicle in front $(i+1)$. It also measures the speed and position of the vehicle in front using the radar $r_i(v_{i+1})$. This work will investigate the possibility to build a consensus model based on several sources of information, along with inference i.e. vehicle i builds its trust from reputation information gathered from vehicle $i+1$ and so on. For example, the v_1 vehicle measures the distance to v_2 and at the same time v_1 receives wireless information from v_2 $w_1(v_2, ...)$, which makes it possible for v_1 to compare the behaviour from the two data sources and thus establish trust about v_2. In this way information can be combined to create trust between all road users within the traffic system.

We assume that computational trust is based on similar principles as human trust and therefore, predictability of the other vehicles will be investigated. The project will explore what variables can be used as a response and what variables can be used as predictors. The starting-point is to model the speed and lane change for a preceding vehicle as a response to the current speed, acceleration and lane position. When the radar information and V2V information are conformably we will proceed to also elaborate on inference to incorporate more vehicles, and thus more signals, into the model in order to build trust for more agents in a wider neighbourhood.

An example of what may be studied in this project is the proximity matrix. Proximity of two observations $\mathbf{x}_i$ and $\mathbf{x}_j$ estimated using only one tree attains a value of zero or one. This is a very rough–binary–measure. As the number of trees in RF grows, the proximity estimate becomes more accurate due to averaging. A large number of trees is necessary to get stable estimates of data proximity [18]. It is not uncommon, however, that random forests of rather few trees are used. A more elaborate estimate of data proximity is needed in such cases.

This feature is particularly interesting for this project since the available data

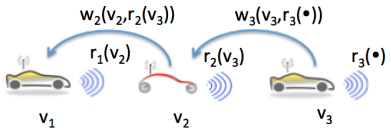

Figure 2: Illustration of the trust model concept. The v_1 vehicle measures the distance to v_2 and at the same time v_1 receives wireless information from v_2 $w(v_2, ...)$, which makes it possible for v_1 to compare the behaviour from the two data sources and thus establish trust about v_2. In this way information can be combined to create trust between all road users within the traffic system.

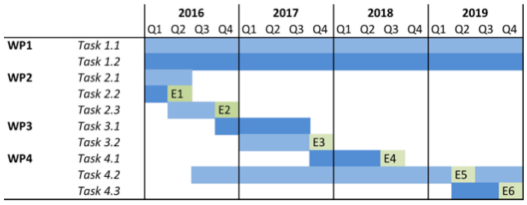

Figure 3: Time plan.

in normal traffic situations is limited and the models that will be established to build trust need to be efficient i.e. possibly contain few trees.

In our previous work a novel approach to estimate data proximity in random forests is proposed [11]. The approach is based on measuring distance between two terminal nodes of a decision tree occupied by observations $\mathbf{x}_i$ and $\mathbf{x}_j$. We suggest assessing proximity of observations $\mathbf{x}_i$ and $\mathbf{x}_j$ according to the following equation:

$$p_{ij} = \frac{1}{K} \sum_{k}^{K} 1/(e^{w \cdot g_{ijk}}) \tag{1}$$

where k runs over the K trees, for which both $\mathbf{x}_i$ and $\mathbf{x}_j$ are among the OOB samples, w is a parameter, and g is the number of tree branches between the two terminal nodes occupied by $\mathbf{x}_i$ and $\mathbf{x}_j$.

We found that the proposed technique improves the data proximity estimate, especially when random forests are made of a small number of trees. This quality is especially useful when building models using data from the fast changing and heterogeneous cooperative intelligent transportation system.

Once a model of trust is created it may be necessary to be able to fuse different models to create the final trust. For this e.g. the Dempster-Shafer theory or a Fuzzy logic-based approach may be investigated as discussed in [12]. In our previous work a SOM was used for weighting the output of multiple models [9, 8].

3.2 Time plan

The project will be executed according to the time plan in Fig. 3 where E1-E6 indicate the expected results in the form of publications.

3.3 Work package description

WP1: Project Management

This work package includes planning and follow up on the tasks and deliverables of the project as well as the financial management. Risk and quality management is also included in order to secure the progress of the project. It also includes dissemination of results and networking in order to have interaction with other researchers and interested stakeholders. In addition we plan to visit other research organizations and invite speakers, arrange workshops and seminars in this WP. Furthermore it includes interaction with other research projects e.g. TINA-AIR (Trust in Automated Systems - Action Intention Recognition) which focuses on human machine interaction (financed by the Knowledge Foundation) where Viktoria is participating. Another project is CHOReVOLUTION (financed by the European Commission within the H2020 program) which is about the establishment of choreography-based middleware for building web-services within the future Internet. These building blocks are also a natural part in the future C-ITS network.

Task 1.1 Project planning and follow up

Task 1.2 Dissemination of the project results, arrange workshops and seminars and visit other research organizations and participate at conferences

WP2: Identification of data sources

The second work package defines the scenarios and the available data, both from on-board sensors, from V2V/V2X according to current standard (ITS-G5) and from on-board sensors located on other vehicles. This work package also includes the generation of such data in order to perform the research in the following work packages. The data generation may be made using a traffic and C-ITS simulator such as Veins[1] or VSimRTI[2]. Synergies are expcted with the TINA-AIR project on data sharing where we expect to receive data for the test in Task 4.3.

Taks 2.1 Identification of available data sources

Task 2.2 Definition of scenarios where reputation and trust models will be used

Task 2.3 Preparation of data generation model

Expected result 1 Scenario description and industrial use-cases

Expected result 2 C-ITS data generation model

WP3: Real-time streaming data-mining

This work package includes the data preparation and the extraction of features that later will be used for modelling the reputation and trust. In areas where the traffic is crowded and speed is slow vast amount of data will be available through wireless communication. This calls for adaptive methods to handle and

[1] http://veins.car2x.org
[2] https://www.dcaiti.tu-berlin.de/research/simulation/

filter out information that is important for the current task. In contrast to scenarios where there are few vehicles and the speed is high, when the data will be sparse and every sample is very valuable.

Taks 3.1 Development of data pre-processing methods to handle the characteristics (see Sec. 1) of the C-ITS data and that is able to provide the relevant data for the reputation and trust modelling tools

Task 3.2 Development of data-mining tool and establishment of a theoretical framework for the following work package

Expected result 3 Theoretical framework and C-ITS data generation model

Expected result 4 Real-time streaming data-mining methods

WP4: Reputation and trust modelling

This work package includes the establishment of a reputation model that can be used to model trust in the scenarios defined in Task 2.2. The work is divided into the following tasks:

Taks 4.1 Dividing the modelling into subtasks and link each sub task to the theoretical framework

Task 4.2 Elaborate on the random forest and proximity measure to understand the trade-offs between data size (number of data and dimensions), forest size, computation time and memory requirements

Task 4.3 Demonstrate the application with new data

Expected result 5 New methods for proximity estimation for trust modelling

Expected result 6 Computational models demonstrating reputation and trust modelling

4 Significance

Emerging cooperative and automated technologies have great potential to boost the transportation business in terms of improving safety, throughput and efficiency. Automation requires computational trust to be able to exploit the predicted benefits within C-ITS. Computational trust is required in all C-ITS applications and automated vehicle functions and we foresee large interest and visibility for the results from this project. In current system the trust factor is often neglected and is considered equal to security. This assumption can be dearly bought if the actual information that is transmitted cannot be trusted. This project proposes to work on the research questions related to computational trust from the realistic data and use-cases defined in the beginning of the project.

This research will facilitate both my work as a young leader in the field and my ambition towards becoming professor within this research area. The research project would benefit from my on-going shared employment between Viktoria Swedish ICT and Halmstad University. Furthermore the project can include work from PhD students to further focus the research scope and create impact.

5 Preliminary results

Previously a novel method to estimate proximity from random forests was developed [11]. It showed promising results to improve the proximity value — especially as the number of trees is small. On the one hand it is desirable to have a fundamental model that describes the behaviour, reputation and trust for C-ITS applications. However, in a heterogeneous and fast changing environment such as the transportation system it may be crucial to instead always be able to have a temporal model of the environment. The work in [11] indicates that it is possible to have even better results with fewer trees compared to what is normally suggested. The characteristics of the C-ITS data may cause *cold start* issues, as described in Section 2.1. With few data and the potential to use few trees the proposed method has the potential to rapid creation of trust models that can be used for automated decision making with automated vehicles and C-ITS. The previous results motivate further investigation of random forest as a data-mining tool in this project.

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[14] Roozbeh Kianfar, Bruno Augusto, Alireza Ebadighajari, Usman Hakeem, Josef Nilsson, Ali Raza, Reza S. Tabar, Naga VishnuKanth Irukulapati, Cristofer Englund, Paolo Falcone, Stylianos Papanastasiou, Lennart Svensson, and Henk Wymeersch. Design and Experimental Validation of a Cooperative Driving System in the Grand Cooperative Driving Challenge. *Intelligent Transportation Systems, IEEE Transactions on*, 13(3):994–1007, September 2012.

[15] Teuvo Kohonen. *Self-Organizing Maps*, volume 30 of *Springer Series in Information Sciences*. Springer Berlin Heidelberg, Berlin, Heidelberg, 1995.

[16] Brent Lagesse. Analytical Evaluation of P2P Reputation Systems. *Int. J. Commun. Netw. Distrib. Syst.*, 9(1/2):82–96, 2012.

[17] N Lathia, S Hailes, and L Capra. Trust based collaborative filtering. *IFIPTM 2008 Joint iTrust and PST Conferences on Privacy Trust management and Security*, 2008.

[18] Andy Liaw and Matthew Wiener. Classification and Regression by randomForest. *R news*, 2(December):18–22, 2002.

[19] John O'Donovan and Barry Smyth. Trust in recommender systems. *Proceedings of the 10th international conference on Intelligent user interfaces IUI 05*, 05pages:167, 2005.

[20] Jordi Sabater and Carles Sierra. Review on computational trust and reputation models, 2005.

[21] Xiaoyuan Su and Taghi M. Khoshgoftaar. A Survey of Collaborative Filtering Techniques, 2009.

[22] Vladimir N Vapnik. *Statistical Learning Theory*, volume 2. 1998.

[23] A. Verikas, A. Gelzinis, and M. Bacauskiene. Mining data with random forests: A survey and results of new tests. *Pattern Recognition*, 44(2):330–349, February 2011.

[24] Ian H. Witten and Frank Eibe. *Data mining*. Morgan Kaufmann Publishers, 2nd edition, 2005.

[25] Jie Zhang. A survey on trust management for VANETs. In *Proceedings - International Conference on Advanced Information Networking and Applications, AINA*, pages 105–112, 2011.

[26] Dan Zhu. A hybrid approach for efficient ensembles. *Decision Support Systems*, 48:480–487, 2010.

Interdisciplinarity

My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

Scientific report

Scientific report/Account for scientific activities of previous project

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Budget and research resources

Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

Dedicated time for this project

	Role in the project	Name	Percent of full time
1	Applicant	Cristofer Englund	40
2	Participating researcher	Lei Chen	60

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	2018	2019	Total
1	Applicant	Cristofer Englund	40	385,258	404,520	424,747	445,984	1,660,509
2	Participating researcher	Lei Chen	60	452,995	475,645	499,427	524,399	1,952,466
	Total			838,253	880,165	924,174	970,383	3,612,975

Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

Premises

Type of premises	2016	2017	2018	2019

Running Costs

	Running Cost	Description	2016	2017	2018	2019	Total
1	Resor	Konferens	80,000	80,000	80,000	80,000	320,000
	Total		80,000	80,000	80,000	80,000	320,000

Depreciation costs

Depreciation cost	Description	2016	2017	2018	2019

Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

Total budget

Specified costs	2016	2017	2018	2019	Total, applied	Other costs	Total cost
Salaries including social fees	838,253	880,165	924,174	970,383	3,612,975		3,612,975
Running costs	80,000	80,000	80,000	80,000	320,000		320,000
Depreciation costs					0		0
Premises					0		0
Subtotal	918,253	960,165	1,004,174	1,050,383	3,932,975	0	3,932,975
Indirect costs	348,936	364,863	381,586	399,145	1,494,530		1,494,530
Total project cost	1,267,189	1,325,028	1,385,760	1,449,528	5,427,505	0	5,427,505

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

Löner inkl. Social avgifter concerns the salary for Cristofer Englund (40%) and Lei Chen (60%) of full time during the four years that the project is running.
Driftskostnader concerns travelling costs to be able to visit conferences and visit other research organizations as well as arranging seminars and workshops to create a lively and fruitful research environment at the institue.

Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

Other funding for this project

Funder	Applicant/project leader	Type of grant	Reg no or equiv.	2016	2017	2018	2019

CV

CV

Cristofer Englund
Viktoria Swedish ICT, Lindholmspiren 3A, 417 56 Göteborg
+ 46 (0) 708 56 02 27, cristofer.englund@viktoria.se

HIGHER EDUCATION QUALIFICATIONS

2006	Lic in Electrical Engineering, Chalmers, Sweden
2003	MSc in Computer Science, University of Technology, Sydney Australia /Halmstad University, Sweden
2001	BSc in Electrical Engineering, Halmstad University, Sweden

DEGREE OF DOCTOR

2007	PhD in Electrical Engineering, Chalmers, Sweden, Modelling and controlling an offset lithographic printing process, Supervisor: Antanas Verikas

PRESENT POSITION

2015 –	Adjunct Senior Lecturer, 20% (50% active research), Halmstad University
2011 –	Research Manager, 100% (80% active research), Cooperative Systems, Viktoria Swedish ICT

PREVIOUS POSITIONS

2010 – 2011	Senior Researcher, Active systems, Viktoria Swedish ICT
2008 – 2010	Project Manager, Albany International AB, Sweden
2003 – 2007	PhD Student, Machine Learning and Data mining at Halmstad University and Chalmers, Sweden

RESEARCH GRANS AWARDED IN COMPETITION

2014	CHOReVOLUTION – Future internet middleware for transport applications, EU-H2020
2014	ARV II – Boundary conditions on automated driving, Vinnova – FFI
2013	i-GAME - Interoperable Grand Cooperative Driving Challenge Automated Event, EU-FP7
2013	ARV – Boundary conditions on automated driving, Vinnova – FFI
2013	EQUIPP – Evaluation of hardware for research at AstaZero, RISE
2013	Analysis and visualization of information for predictive maintenance within traffic infrastructure, Västra Götalandsregionen
2012	VICS Verified Information in Cooperative Systems, RISE
2011	Energy Efficient COoperative sysTems EEKOT, Energimyndigheten

NATIONAL AND INTERNATIONAL AWARDS AND PRIZES

Awards	Forskarstipendiat 2007, Stiftelsen Markussens Studiefond

SUPERVISION

Research manager	As research manager at Viktoria Swedish ICT I currently have the responsibility for 7 researchers (6 of which have PhD degree) within Electrical engineering, Computer Science, Cognitive Science, Tele- and wireless-communication. My group is highly cross-disciplinary and together we perform highly appreciated research within one of the most active areas within the automotive field.

MISCELLANEOUS

Commission	Leader of competence are of Traffic Systems at SAFER, Sweden
In media	Development of Online Print Control (http://www.vimeo.com/4029300) Participation in the Grand Cooperative Driving Challenge (http://www.youtube.com/watch?feature=player_embedded&v=7MFkjpKbTIA#!) Service development for autonomous vehicles (Automotive Sweden 2011, http://www.businessregiongoteborg.com/aktiviteterochnyheter/artiklar/industriforskningsinstitutsomutvecklartjansterforfordonsindustrin.5.7f30c2451341eef1dc180002611.html)

SWEDISH ICT VIKTORIA

CV

Lei Chen

Viktoria Swedish ICT
Lindholmspiren 3A, 417 56 Göteborg
+ 46 (0) 767 77 14 49, lei.chen@viktoria.se
www.viktoria.se

HIGHER EDUCATION QUALIFICATIONS

2010	Lic i Infra-informatik, Linköpings Universitet.
2007	MSc i Communication Engineering, Northwestern Polytechnical University, China.
2004	BSc i Communication Engineering, Northwestern Polytechnical University, China.

DEGREE OF DOCTOR

2013	PhD in Infra-informatics, Linköpings Universitet, Sweden, Performance Engineering of Mobile Broadband: Capacity Analysis, Cellular Network Optimization, and Design of In-Building Solutions, Supervisor: Prof. Di Yuan.

CURRENT EMPLOYMENT

2013 –	Senior researcher, Cooperative Systems, Viktoria Swedish ICT.

EMPLOYMENT HISTORY

2011 – 2012	Research fellow, Ranplan Wireless Network Design, Ltd, UK.
2008 – 2013	PhD Student, Department of Science and Technology, Linköping University.

RESEARCH EXPERIENCE

2015 –	EU H2020 Project Chorevolution.
2013 –	EU FP7 Project i-GAME - Interoperable Grand Cooperative Driving Challenge AutoMation Experience.
2007 – 2013	Capacity analysis of wireless ad hoc networks (Co-financed by VR, ELLIIT and CENIIT at Linköping University).
2007 – 2013	EU FP7 Project IAPP@Ranplan on Mobile broadband (UMTS, LTE, …) network planning and optimization.

NATIONAL AND INTERNATIONAL AWARDS AND PRIZES

Awards	Ericsson Research Grant 2011, Ericssons forskningsstiftelse.

MISCELLANEOUS

Teaching & Supervision	Course Network simulation, Linköping University. Project supervision with topic of interference cancellation in ad hoc networks. Master thesis supervision on ”Time-efficient computation for maximum link activation in wireless communication systems”.

Publication list

List of publications: Cristofer Englund

Google scholar is used for obtaining the “Number of citations”

1. Peer-reviewed original articles

[1]* Englund, C., Verikas, A.: A novel approach to estimate proximity in a random forest: An exploratory study. Expert Systems with Applications 39 (2012) 13046 – 13050. Number of citations: 2

[2]* Kianfar, R., Augusto, B., Ebadighajari, A., Hakeem, U., Nilsson, J., Raza, A., Tabar, R.S., Irukulapati, N.V., Englund, C., Falcone, P., Papanastasiou, S., Svensson, L., Wymeersch, H.: Design and experimental validation of a cooperative driving system in the grand cooperative driving challenge. Intelligent Transportation Systems, IEEE Transactions on 13 (2012) 994 – 1007. Number of citations: 23

[3] Englund, C., Verikas, A.: Ink feed control in a web-fed offset printing press. The International Journal of Advanced Manufacturing Technology, 39 (2008) 919–930. Number of citations: 10

[4] Englund, C., Verikas, A.: Ink flow control by multiple models in an offset lithographic printing process. Computers & Industrial Engineering, 55 (2008) 592–605. Number of citations: 5

[5] Englund, C., Verikas, A.: A SOM based data mining strategy for adaptive modelling of an offset lithographic printing process. Engineering Applications of Artificial Intelligence 20 (2007) 391–400. Number of citations: 7

[6]* Englund, C., Verikas, A.: A hybrid approach to outlier detection in the offset lithographic printing process. Engineering Applications of Artificial Intelligence 18 (2005) 759–768. Number of citations: 10

2. Peer-reviewed conference contributions

[7] Shih Yang, L., Vinel, A., Englund, C., Chen, L.: Poster: Adaptive Wave- length Adjustment (AWLA) for Cooperative Speed Harmonization. In: VNC. (2014). Number of citations: 0

[8] Nilsson, M., Englund, C., Amanuel, M.: On the usage of portable electronic devices: a qualiative study of cyclist behaviour. In: International Cycling Safety, Gothenurg (2014). Number of citations: 0

[9] * Englund, C., Chen, L., Voronov, A.: Cooperative speed harmonization for efficient road utilization. In Vinel, A., ed.: Nets4Cars. (2014). Number of citations: 0

[10] Chen, L., Englund, C.: Cooperative ITS - EU standards to accelerate cooperative mobility. (In: The 3rd International Conference on Connected Vehicles & Expo (ICCVE 2014)).

Number of citations: 0

[11] Lindgren, A., Habibovic, A., Amanuel, M., Englund, C.: ITS-solutions for the identification of dangerous goods and non-moving vehicles research within the Stockholm Bypass project. In: In The 6th International sym- posium on Tunnel Safety and Security (ISTSS), Marseille, France (2014). Number of citations: 0

[12] Habibovic, A., Englund, C., Wedlin, J.: Challenges and opportunities in the field of road vehicle automation. In: Submitted for publication in the Proceedings of FISITA 2014 World Automotive Congress, Maastricht, The Netherlands (2014). Number of citations: 0

[13] Nilsson, J., Strandén, L., Englund, C.: Fault model for cooperative semi- automated vehicles. In: Proceedings of the 20th ITS World Congress, Tokyo, Japan (2013). Number of citations: 10

[14]* Englund, C., Nilsson, J., Lidström, K.: Cooperative its application development through semantic standardization. In: FASTZero 2013, Nagoya, Japan (2013). Number of citations: 0

[15] Bergenhem, C., Adolfsson, M., Coelingh, E., Englund, C., Shladover, S., Tsugawa, S.: Overview of platooning systems. In: Proceedings of the 19th ITS World Congress, Vienna, Austria (2012). Number of citations: 16

[16] Nilsson, M., Williander, M., Englund, C.: Commercialisation of intelligent transportation systems: The case of cooperative systems. In: Proceedings of Transport Research Arena (TRA 2012), Athens, Greece (2012). Number of citations: 0

[17] Englund, C., Martinsson, L.: Internal textile fabric structure analysis using 3D x-ray micro-CT volumetric data. In Bigun, J., Verikas, A., eds.: Proceedings SSBA 2009, Symposium on Image Analysis, Halmstad, Sweden, SSBA (2009) 104–108. Number of citations: 0

[18] Larsson, T., Jansson, J., Grante, C., Englund, C.: Cooperative partly automated and coordinated vehicles and transports. In: 2014 National Workshop on Transportation Cyber-Physical Systems, Virginia, USA (2014). Number of citations: 0

3. Monographs

4. Review articles

5. Book and book chapters

[19] Englund, C., Chen, L., Voronov, A., Shih Yang, L.: Future applications of VANETs. In: Vehicular ad hoc Networks. Accepted for publication (2015). Number of citations: 0

[20] Englund, C., Kovaceva, J., Lindman, M., Grönvall, J.: Using random forests for data mining data and drowsy driver classification using FOT data. In Meersman, R., Panetto, H.,

Dillon, T., Rinderle-Ma, S., Dadam, P., Zhou, X., Pearson, S., Ferscha, A., Bergamaschi, S., Cruz, I., eds.: Proceedings of On the Move to Meaningful Internet Systems: OTM 2012. Lecture Notes in Computer Science Volume 5766 of Part II., Rom, Italy, Springer-Verlag (2012) 748–758. Number of citations: 0

[21] Englund, C., Verikas, A.: Combining traditional and neural-based techniques for ink feed control in a newspaper printing press. In Perner, P. eds.: Advances in data mining: theoretical aspects and applications. Lecture Notes in Computer Science Volume 4597., Berlin, Heidelberg, ICDM'07, Springer-Verlag (2007) 214–227. Number of citations: 6

6. Patent (Patents),

7. Open access computer programs or databases you have developed

8. Popular science articles/presentations

List of publications: Lei Chen

Google scholar is used for obtaining the “Number of citations”

1. Peer-reviewed original articles

[1] Mathematical Modeling for Optimal Design of In-Building Distributed Antenna Systems, Lei Chen, Di Yuan. Computer Networks, 2013. Number of citations: 0

[2] *On Optimal Link Activation with Interference Cancellation in Wireless Networking,* Di Yuan, Vangelis Angelakis, Lei Chen, Eleftherios Karipidis, Erik G. Larsson. IEEE Transactions on Vehicular Technology, Submitted. Number of citation: 0

[3] ***** Generalizing and Optimizing Fractional Frequency Reuse in Broadband Cellular Radio Access Networks*, Lei Chen, Di Yuan, EURASIP Journal on Wireless Communications and Networking 2012, 2012(203). Number of citations: 8

[4] *Optimal and collaborative rate selection for interference cancellation in wireless networks*, Vangelis Angelakis, Lei Chen, and Di Yuan, IEEE Communications Letters, 15(8), pp. 819-821, 2011. Number of citations: 4

[5] ***** A New Computational Approach for Maximum Link Activation in Wireless Networks under the SINR Model*, Antonia Capone, Lei Chen, Stefano Gualandi, Di Yuan, IEEE Transaction on Wireless Communications, 10(5), pp. 1368–1372, 2011. Number of citatins: 18

[6] *Coverage Planning for Optimizing HSDPA Performance and Controlling R99 Soft Handover*, Lei Chen, Di Yuan, Telecommunications Systems Journal, 2010, DOI 10.1007/s11235-010-9414-z . Number of citations: 4

[7] *** Solving a Minimum-power Covering Problem with Overlap Constraint for Cellular Network Design*, Lei Chen, Di Yuan, European Journal of Operational Research, 203(3), pp. 714–723, 2009. Number of citations: 12

2. Peer-reviewed conference contributions

[8] *Design of in-building distributed antenna systems: mathematical models and efficient algorithms, Lei Chen*, Di Yuan, Accepted for publication in IEEE ICC 2015 - 4th IEEE International Workshop on Smart Communication Protocols and Algorithms (SCPA 2015), 2015. Number of citations: 0

[9] *Cooperative ITS - EU standards to accelerate cooperative mobility, Lei Chen*, Cristofer Englund, In proceedings of the 3rd International Conference on Connected Vehicles & Expo (ICCVE 2014), 2014. Number of citations: 0

[10] *Cooperative speed harmonization for efficient road utilization, Cristofer Englund, Lei Chen,* Alexey Voronov, In proceedings of the 7th International Workshop on Communication Technologies for Vehicles (Nets4Cars 2014), 2014. Number of citations: 0

[11] *Mathematical modeling for optimal deployment of In-building distributed antenna system,* Lei Chen, Hui Song, Di Yuan, Jie Zhang, IEEE ICCC 2012. Number of citations: 1

[12] *Incentive mechanism for uplink interference avoidance in two-tier macro-femto networks*, Zhu Xiao, Xu Zhang, Shyam Mahato, Lei Chen, Jie Zhang, IEEE VTC2012-Spring, 2012. Number of citations: 2

[13] *A Fully Decentralized and Load-Adaptive Fractional Frequency Reuse Scheme*, Vangelis Angelakis, Lei Chen, Di Yuan, In proceedings of IEEE 19th International Symposium on Modeling, Analysis & Simulation of Computer and Telecommunication Systems (MASCOTS), 2011. Number of citations: 2

[14] *Enhanced Fractional Frequency Reuse for Large-Scale OFDMA Networks with Heterogeneous Cell Layout: Optimization and Performance Evaluation*, Lei Chen and Di Yuan, The IEEE International Conference on Communication Systems. Number of citations: 0

[15] *Generalizing FFR by Flexible Sub-band Allocation in OFDMA Networks with Irregular Cell Layout*, Lei Chen and Di Yuan, Second International Workshop on Planning and Optimization of Wireless Communication Networks (PlanNet2010), WCNC 2010. Number of citations: 12

[16] ***** Generalized Frequency Reuse Schemes for OFDMA Networks: Optimization and Comparison*, Lei Chen and Di Yuan, VTC 2010 Spring. Number of citations: 12

[17] *Beyond conventional fractional frequency reuse for networks with irregular cell layout: An optimization approach and performance evaluation*, Lei Chen and Di Yuan, The 5th Annual International Wireless Internet Conference, WICON2010. Number of citations: 3

[18] ***** Soft Frequency Reuse in Large Networks with Irregular Cell Pattern: How Much Gains To Expect?,* Lei Chen and Di Yuan, IEEE PIMRC'09. Number of citations: 21

[19] *Achieving Higher HSDPA Performance and Preserving R99 Soft Handover Control by Large Scale Optimization in CPICH Coverage Planning*, Lei Chen, Di Yuan, IEEE eighth Annual Wireless Telecommunications Symposium (WTS2009). Number of citations: 2

[20] *Fast Algorithm for Large-Scale UMTS Coverage Planning with Soft Handover Consideration*, Lei Chen, Di Yuan, The 5th International Wireless Communications and Mobile Computing Conference (IWCMC2009). Number of citations: 0

[21] *CPICH Power planning for optimizing HSDPA and R99 SHO performance mathematical modelling and solution approach*, Lei Chen, Di Yuan, IFIP Wireless Days Conference 2008. Number of citations: 3

[22] *Automated Planning of CPICH Power for enhancing HSDPA Performance at Cell Edges with Preserved Control of R99 Soft Handover*, Lei Chen, Di Yuan, IEEE International Conference on Communications (ICC2008). Number of citations: 1

3. Monographs

4. Review articles

5. Book and book chapters

[23] ***Future applications of VANETs.*** Englund, C., **Chen, L.**, Voronov, A., Shih Yang, L.: In: Vehicular ad hoc Networks. Accepted for publication (2015). Number of citations: 0

6. Patent (Patents),

7. Open access computer programs or databases you have developed

8. Popular science articles/presentations

List of publications

CV

Name: Cristofer Englund	**Doctorial degree:** 2007-11-30
Birthdate: 19771023	**Academic title:** Doktor
Gender: Male	**Employer:** Högskolan i Halmstad

Research education

Dissertation title (swe)

Dissertation title (en)

Modelling and controlling an offset lithographic printing process

Organisation	Unit	Supervisor
Chalmers tekniska högskola, Sweden Sweden - Higher education Institutes	Inst för Signaler och system	Antanas Verikas

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20205. Signalbehandling	978-91-7385-014-8	2007-11-30

CV

Name: Lei Chen	**Doctorial degree:** 2013-04-07
Birthdate: 19810724	**Academic title:** Doktor
Gender: Male	**Employer:** Viktoria Swedish ICT

Research education

Dissertation title (swe)
Performance Engineering of Mobile Broadband

Dissertation title (en)
Performance Engineering of Mobile Broadband

Organisation	Unit	Supervisor
Linköpings universitet, Sweden Sweden - Higher education Institutes	Institutionen för teknik och naturvetenskap (ITN)	Di Yuan

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20204. Telekommunikation	978-91-7519-675-6	2013-04-07

Publications

Name: Cristofer Englund	**Doctorial degree:** 2007-11-30
Birthdate: 19771023	**Academic title:** Doktor
Gender: Male	**Employer:** Högskolan i Halmstad

Englund, Cristofer has not added any publications to the application.

Publications

Name: Lei Chen	**Doctorial degree:** 2013-04-07
Birthdate: 19810724	**Academic title:** Doktor
Gender: Male	**Employer:** Viktoria Swedish ICT

Chen, Lei has not added any publications to the application.

Register

Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.

Applications with an organisation as applicant is automatically signed when the application is registered.