Application

2015-03-31

2015-03958 **Knorn, Steffi** **NT-14**

Information about applicant

Name: Steffi Knorn
Doctorial degree: 2013-09-12
Birthdate: 19840130
Academic title: Doktor
Gender: Female
Employer: No current employer
Administrating organisation: Uppsala universitet
Project site: Inst för teknikvetenskaper

Information about application

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Participants

Name: Subhrakanti Dey
Doctorial degree: 1996-04-23
Birthdate: 19680919
Academic title: Professor
Gender: Male
Employer: Uppsala universitet

Name: Anders Ahlén
Doctorial degree: 1986-05-16
Birthdate: 19531117
Academic title: Professor
Gender: Male
Employer: Uppsala universitet

Descriptive data

Project info

Project title (Swedish)*

Robust strängstabilitet och skalbarhet för multiagentsystem

Project title (English)*

Robust String Stability and Scalability of Multi-Agent Systems

Abstract (English)*

Multi-agent systems are implemented in many different areas and forms in many technical applications today and will become even more important in the future. While an important body of work has appeared over the years, many key questions and problems have not been addressed yet. In this context, we will consider some key questions regarding the scalability with respect to the norm of the error transients and the robustness with respect to communication and measurement imperfections. This will include analysing the effects of communication and measurement imperfections as well as model uncertainties on string stability and designing suitable control algorithms to ensure string stability of unidirectional and bidirectional vehicle strings. Further, we will analyse transient bounds and develop suitable control algorithms in undirected and directed consensus networks with and without communication and measurement constraints. We will take the novel approach of combining methods proven to be suitable to study string stability (e.g. frequency domain analysis, 2D systems theory and port-Hamiltonian systems theory), methods suitable for handling of communication imperfections (e.g. stochastic Lyapunov functions) and results derived in the classic consensus literature (e.g. graph theory). Research in this area will contribute to theoretical advances in both the fields of string stability and consensus networks, and will enable safe operation of these networks in realistic settings.

Popular scientific description (Swedish)*

Dagens tekniska system byggs mer och mer av nätverk av individuella komponenter. Det finns flera skäl till detta såsom till exempel att delar tidigare har fungerat oberoende av varandra eller för att ett fåtal större komponenter inte kan lösa de problem som behöver hanteras.

Ett exempel på system med flera ihopkopplade komponenter är så kallade fordonståg där flera fordon körs automatiskt i rad utan inbördes mekaniska kopplingar. Det finns många fördelar med detta jämfört med att fordonen framförs av flera oberoende förare: automatisk körning kan göras säkrare snabbare, mer effektiv och mer upplevelseberikande. Emellertid så finns det en del tekniska problem som måste hanteras innan man fullt ut kan lita på de automatiska systemen. Ett sådant problem med till exempel fordonståg är att det kan uppstå gummibandseffekter eller chockvågor som fortplantar sig genom tåget: tåget trycks då ihop eller dras isär, en effekt som man kan se vid manuell körning i köer.

Ett litet fel i t ex avståndsmätnigen mellan de första fordonen i tåget kan fortplanta sig så att fordonen kraschar i varandra eller att tåget dras isär så mycket att det inte längre kan fungera som ett tåg. Det kan också hända att tåget står helt stilla. Dessa effekter kan också observeras på trafikerade vägar där köer helt plötsligt kan uppstå utan någon uppenbar anledning som till exempel vägarbete eller olycka.

Denna typ av effekter måste undvikas till varje pris om fordonståg ska kunna köras på vanliga vägar i hög hastighet och med korta avstånd mellan fordonen. Trots att det finns fungerande algoritmer för denna typ av tillämpningar så förutsätter de att alla sensorer, liksom kommunikationen dem emellan, fungerar felfritt och att mätningarna är precisa och utan störningar. Men vad händer om någon sensor falerar eller om mätningarna är felaktiga, eller om kommunikationen mellan fordonen bryts? Det är lätt att inse att dessa händelser kan leda till oönskade effekter även om det bara är under korta tider som händelserna inträffar. Denna typ av frågeställningar kommer att undersökas i det föreslagna projektet. Andra typer av nätverk är ofta distribuerade och består av mindre delar till exempel sensorer och/eller regulatorer och aktuatorer. Skälet till detta är att det i flera fall inte är lämpligt att ha en enda central nätverksmanager som sköter allt. Ett intuitivt exempel är om man vill mäta medeltemperaturen i en stor lokal eller i en hel byggnad med flera sensorer utplacerade på olika ställen. Att koordiera dessa mätningar och komma överens om en medeltemeratur är i denna typ av nätverk ofta genomfört med hjälp av så kallade konsensusalgoritmer.

Det anses allmänt att denna typ av (distribuerade) nätverk kommer att bli alltmer vanliga i framtiden och att fler och fler mindre nätverk kopplas ihop till större enheter. Det finns flera exempel på sådana nätverk. Ett exempel är det så kallade "smart grid", där bland annat elbilar, verktyg, hushållsmaskiner och luftkonditioneringar med mera är tänkt att kopplas ihop med det elektriska nätet och Internet. Man får på detta sätt nya möjligheter att förbättra existerande nätverk och göra dem mer robusta.

Detta projekt kommer att undersöka ovan beskrivna ofta både komplexa och distribuerade nätverk och samverkan mellan de ingående enheterna. Vi kommer bland annat att studera hur kommunikationsavbrott mellan enheter och mät- och sensorfel påverkar fordonståg och liknande nätverk. Vi kommer speciellt att studera hur ovan beskrivna gummibandseffekter eller chockvågor ska kunna undvikas i fordonståg och liknade nätverk och vi kommer att utveckla nya robusta regleralgoritmer för att garantera både prestanda och säkerhet i dessa och andra moderna tekniska nätverk.

Project period

Number of project years*

3

Calculated project time*

2016-01-01 - 2018-12-31

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*	2. Teknik > 202. Elektroteknik och elektronik > 20202. Reglerteknik 2. Teknik > 202. Elektroteknik och elektronik > 20203. Kommunikationssystem

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

Keyword 1*

multi-agent systems

Keyword 2*

platooning

Keyword 3*

networked control

Keyword 4

string stability

Keyword 5

scalability

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*

No experiments with animals or humans

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

RESEARCH PLAN

Robust String Stability and Scalability of Multi-Agent Systems

1 Purpose and aims

Automatic control has become an integral part of modern live, particularly since wireless networks and networked control came into play. Smooth operation and robust control is crucial in many areas including, for example, the use of personal communication devices, a stable and reliable electrical grid, internet congestion control, control of modern industrial processes and production lines, and driving of modern vehicles. Today's and future cars could almost be described as "rolling sensor and actuator networks" with sensors monitoring and computers controlling almost all aspects of the vehicle. This includes safety related control loops such as automatic braking, lane keeping, maintaining safety distances, and compensating side drift due to wind or road slope; control to improve efficiency such as optimal fuel consumption, cruise control and slip control; and control to increase the passengers' comfort such as controlling the temperature and the radio volume automatically.

Recently, there has been a strong push towards automatic driving. Several companies have conducted project in this area, see e.g. [1–3]. Cars then have to rely on accurate measurements of surrounding vehicles as well as reliable Vehicle-to-Vehicle and Vehicle-to-Infrastructure wireless communication. The evolution of wireless communication and the availability of cheap and accurate sensors will enable the widespread use of fully automated cars in the not so distant future.

A major concern in this context is the string stability of vehicle platoons. In its simplest form each vehicle aims to follow its direct predecessor while the first vehicle follows a given reference. Achieving stability in the usual Lyapunov sense is trivial if it is assumed that all vehicles are stable systems due to the simple network structure. It is also trivial in most scenarios to ensure that all error signals approach zero in finite time. However, the main concern in vehicle platoons are the transients of the error signals. As disturbances at the beginning of the string propagate down stream, string stability must be guaranteed. That is, the errors must not be amplified when travelling through the string. Or, in other words, it is required that there exists an upper bound on all error signals independently of number of car N.

While manufacturers of self driving cars have solved many problems such as lane keeping, turning, automatic parking and lane changes, the issue of string stability has not yet been considered by the industry. A lot of test suggest that such self driving cars drive safely and efficiently on roads with human driven cars. However, it is questionable if self driving cars could operate safely if their percentage grows significantly.

Different control solutions have been proposed to guarantee string stability in a variety of vehicle platoon settings, see e.g. [4–11]. Robustness of these control algorithms with respect to sensor failure, noise, time delay, communication losses, sampling, and quantisation has, however, been largely ignored to this date. It is clear that understanding the influence of different communication imperfections[1] as well as developing suitable *robust* control algorithms is a major challenge.

More and more other technical devices (besides passenger cars) are operated automatically. Additionally, in an increasing number of areas, different devices are connected to networks. This development is made possible due to the availability of more powerful, affordable and compact wireless sensors and advances in the area of wireless communication. A common control objective in this context is *consensus*, where agents in a network communicate with neighbouring agents in order to converge to a common state. In case one or more agents have access to a global reference signal, the network is *pinned* and the overall control objective is modified to converging to the reference signal instead of a weighted average of the states' initial conditions.

Despite very similar agent dynamics and controller constraints in the vehicle platoon and consensus and pinning literature, results obtained in the consensus and pinning area cannot be applied directly to vehicle platoons. Many consensus and pinning algorithms have been developed to ensure that a decentralised network of agents reaches the desired steady state in finite time despite communication constraints, varying topologies, or nonlinear or heterogeneous agent dynamics. However,

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[1] Dropouts will be a major issue in this context and has to be designed for.

transient behaviour of the system states on their way to the desired equilibrium (such as, for example, the maximal deviation from the desired equilibrium over time) has widely been neglected as long as the transients remain bounded for some bounded network size. Thus, the equivalent of "string stability" in networks other then (vehicle) strings[2] has not been investigated.

Adapting control algorithms to ensure string stability despite communication constraints would constitute a significant step towards a safe traffic system with a large percentage of self driving cars. Also, guaranteeing the equivalent of string stability while allowing topologies to differ from the usual string structure and vary over time would open a whole new aspect in consensus and pinning research. If successful, upper bounds on error transients could be guaranteed independently of the network size. This would lead to a guaranteed level of performance and could help to make consensus and pinning networks safer, more cost effective and more relevant to other safety related areas where transient bounds are of utmost importance.

Specifically, the aims of the project are:

- Analysis of **effects of communication constraints, measurement imperfections, quantisation and drop-outs on string stability of vehicle platoons** and derivation of suitable robust control algorithms given certain communication and sensor specifications and performance constraints;
- Analysis of **transient scalability in directed and undirected consensus and pinning networks with unimpaired sensing and communication** and development of suitable control algorithms;
- Analysis of **transient scalability in consensus and pinning networks under communication and measurement constraints** and development of suitable control algorithms.

2 Survey of the field

Three major topics are of particular relevant for our proposal: (i) string stability of vehicle platoons without communication constraints, (ii) string stability of vehicle platoons subject to communication constraints, measurement imperfections and drop-outs, and (iii) distributed consensus algorithms and pinning control.

String stability of vehicle platoons without communication constraints: The first formal definition of string stability in [6] requires the norm of all states of the entire string to be bounded independently of the number of vehicles N for a given bound on the initial conditions. In case where only information of preceding vehicles is used, a string is called "unidirectional", otherwise "bidirectional". The usual vehicle model involves two integrators in the open loop and is often considered to be linear. It has been shown in [12, 13], that it is not possible to achieve string stability in a unidirectional or bidirectional string of identical linear systems with two integrators in the open loop when only using information of the nearest neighbours, and aiming for constant inter-vehicle spacing. This result is independent of the particular plant or controller model in place.

Different strategies have been proposed in the literature to guarantee string stability of unidirectional strings: In [4] string stability was guaranteed using a sufficiently large velocity dependent distance called the "time headway" h. Instead of a fixed inter-vehicle distance the desired distance towards the direct predecessor grows with the velocity v. The simplest realisation is the "constant time headway policy" where vehicle i aims to maintain a distance of hv_i towards vehicle $i-1$. When a constant spacing policy is required, however, string stability can be guaranteed using suitable information of the lead vehicle. Different communication settings and a discussion about which states of the lead vehicle are necessary to guarantee string stability can be found in [5]. Another approach is using a heterogeneous string structure, that is considering a string of vehicles with non identical dynamics. In [8], a design for a local controller that depends on the position i was presented. Even though uniformly bounded local errors could be guaranteed, it should be noted that the control parameters do grow linearly with i and thus are unbounded for an infinite string. In [10] it was shown that a heterogeneous string is string stable if the local transfer function $|G_i(j\omega)|$ is less than or equal

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[2] i.e. a network that is a complex "web" of interconnected agents, instead of just a "chain"

to 1 for all ω and i. Later in [11] an infimal average time headway was derived to permit heterogeneous string stability. Although most researchers have worked on linear string models to analyse string stability there are also some results for nonlinear systems. In [14] the authors prove that under some conditions strings of nonlinear systems using the lead velocity, the lead acceleration and local measurements are string stable. In [6] a global Lipschitz condition is used to guarantee string stability of nonlinear systems with sufficiently small Lipschitz constants or “weak coupling”.

String stability of bidirectional strings has also received some interest: [9] showed that string stability can be guaranteed given a sufficiently large coupling with the leader position. [15] considered a linear, bidirectional string of N vehicles. It is shown that choosing asymmetric weights for the forward and backward error achieves better performance compared to symmetric weights. However, knowledge of the steady state, or reference velocity is needed. Both proposed solutions depend on either perfect communication between the leading vehicle and the rest of the string or perfect knowledge of the reference signal. A different approach was considered in [7]. Modelling a symmetric bidirectional string as a mass-spring-damper system, it is shown that string stability with constant spacing can be guaranteed if some control parameters grow with the string length N. This seems undesirable in practise, since controller parameters cannot be chosen infinitely high, meaning the string cannot be extended without bound.

String stability of vehicle platoons subject to communication and measurement imperfections: Some researchers explored the influence of time delays in vehicle platoons, see e.g. [16–22]. A unidirectional, homogeneous platoon is studied in [16]. The distance towards the preceding vehicle and its velocity is assumed to be measured accurately and without delay. The position and velocity of the lead vehicle are received via wireless communications (subject to delay). An upper bound on the delay is given to guarantee asymptotic stability of the subsystems. But it is unclear if the resulting system is string stable.

The authors in [17] consider a similar scenario where the communication between the leader and the remaining vehicles is organised using tokens. The local control law is triggered by either the receipt of the lead vehicle information or the preceding vehicle information. Then, string stability cannot hold even for infinitesimally small lead vehicle information delays. In case all controllers are synchronised, string stability can be guaranteed only if the time delay is small enough. However, small clock jitter or simple delays in sensing the predecessors states lead to string instability.

Sufficient controller gains to guarantee string stability in a similar scenario have also been proposed in [19, 21], but the influence of asynchronous controllers is not discussed. The authors in [22] discuss two different scenarios, where either the global position error towards the leader or just the leader velocity is required. In case of isolated time delays (effecting only one vehicle in the string) string stability can be guaranteed. However, when allowing multi-step string relay communications (leading to an increasing time delay along the string), string stability with respect to the leader error cannot be guaranteed .

As in the case of idealistic system descriptions (i.e. without delays or noise), string stability can also be achieved using a constant time headway policy (without the need of any lead vehicle information). However, sensing or other delays or actuator lag might still impair string stability of the system. Using sliding mode control in [18] it was shown that string stability can be guaranteed if the time headway is sufficiently big. Simulations in [20] give bounds on the maximum allowable ratio of constant time delays and sampling intervals given a constant time headway. These results are further extended in [23] when considering sampling of the control input.

The effects of communication losses in vehicle following systems (and suitable robust control laws) have been studied in [24, 25]. But how these control laws perform with increasing string sizes (string stability) was not discussed. Similarly, an optimal quadratic cost controller is introduced for a system with wireless communication (between the leader and the remaining vehicles) subject to quantisation, time-delay and packet-losses in [26]. But, again, string stability is not discussed. Assuming the lead vehicles information is quantised and transmitted to the following vehicles subject to time delays and packet drop-outs, sufficient conditions on the control parameters to guarantee string stability are given in [27].

Distributed consensus algorithms and pinning control: In its simplest form, a consensus algorithm is implemented in a network of identical single or double integrator agents. The local control signals are usually chosen as a (possibly weighted) average of the state(s) of neighbouring agents and the state(s) of the agent itself. The underlying communication structure is usually described by a graph, and given appropriate connectivity conditions, it can be guaranteed that the system will reach consensus, [28–32]. In case the network topology switches between a finite set of graphs, the union of the collection of interaction graphs across some bounded time intervals must have a spanning tree frequently enough to ensure consensus, [33, 34].

A more general setting is to allow time-varying topologies. This can be a result of employing the “nearest neighbour rule” where each agent communicates only with all neighbours within a specified radius or is caused by network weights tuning. Studies in [29, 35] revealed that using the nearest neighbour rule, the network achieves consensus regardless of switching in the neighbouring graph, as long as the graph remains connected at all times. Weaker conditions such as joint connectivity were proposed in [36, 37].

Consensusability, i.e., the ability of a network to reach consensus, has also been studied for a large variety of deviations from the standard model discussed above. Usually the information of agents is sampled and sent periodically. [38] introduced a framework to study consensus problems via sampled control and sampling delay. Convergence of two sampled-data coordination algorithms is studied in [39, 40]. Also, due to bandwidth constraints data is often quantised before transmission. A distributed algorithm ensuring consensus in the presence of quantisation can, for example, be found in [41] showing that a quantised gossip algorithm leads to a quantised consensus. The robustness of consensus in discrete-time single-integrator multi-agent networks to arbitrarily large delays has been shown in [42, 43]. Consensus of continuous time agents with discrete time, asynchronous information transmission, a time-varying topology and bounded time-varying delays has been investigated in [34].

Another common control objective in multi agent systems is pinning control. Apart from local consensus algorithms a fraction of the nodes is connected to a reference signal. These nodes are thus “pinned” to the reference and can be regarded as leaders. Some examples of pinning control for networks of first-order agents can be found in [44–47]. The results show that under suitable conditions on the communication topology, all agents approach a prescribed value if a small fraction of them are controlled by simple feedback control. These results were extended to second-order consensus of double integrators for instance in [32]. If a group reference velocity is available to each agent, then consensus is reached asymptotically if the directed interaction graph has a directed spanning tree and the gain for the velocity matching with the group reference velocity is above a certain bound.

Unfortunately, the concept of transient scalability for arbitrary networks as a logical extension of string stability has not been considered yet. Hence, its is largely unknown how pinned consensus networks should be designed such that the maximal deviation from the desired equilibrium are bounded independently of the number of agents in the network.

3 Project description

We will describe the research plan, methods and techniques for each research objective.

Effects of communication and measurement constraints on string stability of vehicle platoons: System dynamics in unidirectional and bidirectional vehicle strings differ significantly from each other. Thus, it is useful to distinguish between the two cases and consider the following research problems: analysis of effects of communication constraints, measurement imperfections and drop-outs on string stability and design of suitable control algorithms to ensure string stability of (i) unidirectional vehicle strings, and (ii) bidirectional vehicle strings.

Some results on **problem (i)** are already available in the string stability literature (such as discussed in the literature review above). However, many open problems arising in asynchronous strings, platoons with increasing delay towards the end of the string or communication drop-outs and sensor failure still remain. Due to the unidirectional communication structure, different tools can be used to analyse the string dynamics and it seems reasonable to build our analysis on the existing theory.

For instance, homogeneous strings can be modelled as two-dimensional (2D) systems (treating the time t as the first and the position in the string i as the second independent variable) as proposed in [48, 49]. Then, stability in the 2D sense means string stability of the underlying vehicle string. There exists suitable frameworks for 2D systems with time-delays, such as [50], and some results on how to design stabilising controllers, e.g., [51, 52]. Unfortunately, most stability and controller design results available for 2D systems, including [51, 52], cannot be applied directly to vehicle string systems due to an unavoidable singularity on the stability boundary. Thus, these results have to be extended to cover such marginally stable systems.

- Our approach will be to combine the available results on stability of 2D systems subject to delays and the existing sufficient stability contains for marginally stable 2D systems in the time domain in [48, 49] and the frequency domain in [53]. We expect that the influence of quantisation (assuming the use of high rate quantisation approximations) and noise will be similar to the influence of external disturbances acting on the system. Results discussing the disturbance-to-error transfer function in the frequency domain, [53], will be extended to study the effects of noise and quantisation.
- In case heterogeneous strings are considered, the 2D systems approach has to be adapted. We will aim to model the heterogeneous string as a 2D system using the average vehicle dynamics as the nominal case and treating deviations from it as model uncertainties, as it has been done, for example, for systems without singularities on the stability boundary in [52].
- The problem of packet drop-outs has been studied in [24–26]. Although these results are useful for designing vehicle strings that are asymptotically stable in the Lyapunov sense, string stability has not been discussed. Our approach there will be to extend these results and derive sufficient conditions to ensure string stability. Another approach will be to extend the existing theory of stochastic Lyapunov theory. In particular, it seems promising to extend ideas and results presented in [54, 55] to study the effect of communication drop-outs on string stability. (We expect the effects of sensor failures to be similar.)

To solve **problem (ii)** we will extend the existing preliminary results presented in [56] (see also Section 6 “Preliminary results” in this Appendix). The analysis of measurement noise and offsets is based on the description of the string as a port-Hamiltonian system as proposed in [56]. Of particular importance here is the fact that, in a bidirectional string, vehicles need to sense the position error towards both preceding and following vehicles. Thus, the distances between a pair of cars might be measured by both vehicles individually. In this case, the proposed solution reported in [57] requires each pair of agents to agree on a common measurement (for example the average of both measurements) to ensure that the effects of measurement uncertainties do not accumulate at one end of the string. However, this solution relies on wireless communications between the agents. Even in the best possible scenario without drop-outs, communication delay will influence the dynamics of the string. In order to account for these delays and to analyse their influence on string stability we will build on the existing theory of delayed port-Hamiltonian systems as discussed in [58]. We expect the cases of drop-outs and sensor failures to be similar to allowing a time-varying communication structure to account for intermittent link breakage. In order to synthesise suitable controllers and communication structures we will investigate which additional communication links are necessary to maintain a string stable formation using results from the area of graph theory. Further, it will be necessary to develop algorithms to successfully detect sensor and communication failures and adjust the control signal accordingly.

Transient scalability in directed and undirected consensus and pinning networks with unimpaired sensing and communication: Similar to the problem of string stability, the transient dynamics will depend on the communication structure. We will distinguish between the following tasks: analysis of transient bounds and development of suitable control algorithms in (i) undirected networks, and (ii) directed networks.

The approaches to deal with **task (i)** will be similar to results reported in [48, 53, 56, 59]. It is shown in [60] that undirected systems can also be written as a port-Hamiltonian system. Graph theory was used to study the eigenvalues of the extended or perturbed Laplacian matrix, denoted $\bar{L}$, since it is well known that the spectrum of the unperturbed Laplacian L is related to the connectivity of the underlying graph. (See also Section 6 “Preliminary results” in this Appendix.)

We expect that these methods cannot be applied directly to directed consensus networks studied in **task (ii)**. However, there exists a rich literature studying consensus and pinning of directed networks using other results of graph theory. Our approach will be to build on these results.

Transient scalability in consensus and pinning networks under communication and measurement constraints: As above, the transient dynamics will depend on the communication structure. Hence, we will again distinguish between the tasks of analysing transient bounds and developing suitable control algorithms in (i) undirected networks, and (ii) directed networks. To solve **task (i)**, we plan to extend the results reported in [60] and discussed in “Preliminary results” to systems with communication constraints and measurement imperfections by extending the findings in [57, 59]. As discussed above, it is likely that these results will not hold for directed networks. Thus, we will build on existing results on consensus and pinning of directed networks to solve **task (ii)**.

4 Project time line, implementation and organisation

The project will be led by Dr Steffi Knorn (SK) who will be engaged in all parts of the project at various levels from hands on research to supervision/co-supervision of the PhD student (NN) together with Prof Anders Ahlén (AA) and Prof Subhrakanti Dey (SD). During 2016 we will enrol a PhD student to work on the effects of communication constraints, measurement imperfections and drop-outs on string stability in bidirectional strings and transient scalability in undirected networks. AA will work on the effects of communication and measurement imperfections on string stability and SD will work on the scalability of networks. The rest of the project is organised according to Table 1.

Table 1: Sub-projects, and active people each year: Dr S. Knorn (SK), Prof A. Ahlén (AA), Prof S. Dey (SD), PhD student (NN)

Research sub-project	2016	2017	2018
Effects of communication and measurement...:			
Problem (i)	SK, AA	SK, AA	-
Problem (ii)	SK, AA, NN	SK, AA, NN	SK, AA, NN
Transient scalability in unimpaired networks:			
Task (i)	SK, SD, NN	NN	-
Task (ii)	-	SK, SD, NN	SK, SD, NN
Transient scalability in networks with constraints:			
Task (i)	SK, SD, NN	SK, NN	-
Task (ii)	-	SK, SD, NN	SK, SD, NN

5 Significance

This project is significant in that it will enable the implementation of algorithms ensuring bounded transients in safety crucial applications (such as vehicle strings) under realistic conditions. Further, it opens an entirely new approach to “scalability” in networks subject to the network’s transients, which will be beneficial to all areas where decentralised sensing and actuation is used.

Traditionally, research has focused solely on the stability of these systems to ensure that all states remain bounded and all agents reach a desired state. This project aims to ensure a stronger requirement: String stability and transient scalability imply that not only all states remain bounded and ultimately converge, but the existence of a global bound on all transients of the system independently of the size of the system, i.e., the number of agents. This is particularly important for safety concerns in some areas such as vehicle platoons, but will also become more important in other areas.

6 Preliminary results

In this section we describe some preliminary results. We will first focus on [57,59], where Knorn (applicant), Donaire, Agüero and Middleton (some of the proposed collaborators) study the **effect of measurement uncertainties on string stability of bidirectional vehicle strings**.

Consider a string of N vehicles driving in a platoon. All vehicles should maintain a specified distance towards their direct predecessor and direct follower. The first vehicle uses a specified reference signal with constant velocity v_0 as its virtual predecessor and the last vehicle's control is only driven by its forward position error. It has been shown in [48,56] that string stability of the system with perfect measurements is guaranteed using a local controller and integral action.

Consider each vehicle to have two radar sensors to measure the distance towards the preceding and following vehicle. The distance between vehicle i and its direct follower $i+1$, denoted by Δ_i, is measured by both vehicles. It is possible that both radar sensors might be effected by static measurement offsets $\hat{\Delta}_{\mathrm{b},i}$ (backward offset of vehicle i) and $\hat{\Delta}_{\mathrm{f},i}$ (forward offset of vehicle $i+1$), which are not identical, that is $\hat{\Delta}_{\mathrm{b},i} \neq \hat{\Delta}_{\mathrm{f},i}$. Additionally, it is possible that both measurements are corrupted by non identical dynamic measurement noise $\breve{\Delta}_{\mathrm{b},i}(t)$ and $\breve{\Delta}_{\mathrm{f},i}(t)$, respectively.

If only constant measurement offsets are present, it is shown in [59] that the steady state value of the first inter vehicle difference will accumulate at the beginning of the string if the forward measurement offsets are consistently greater or smaller compared to the backward measurement offsets. This can lead to a pile up crash or to very large distances and the breakup of the platoon. In case non identical dynamic measurement noise is considered, the effect of such measurement inaccuracies also accumulates at the beginning of the string, which leads to string instability, as reported in [57]. This does not only imply a serious risk of crashes but also leads to unacceptable driving performance and actuator saturation. Note that even if all measurements are filtered, measurement noise can be expected to be smaller but still present. Thus, filtering decreases the amount of accumulated noise but does not solve the underlying issue of string instability.

A solution to avoid the potential accumulation of measurement offsets or measurement noise is presented in [57]: If every vehicle can communicate its distance measurement towards its direct neighbours, a common value (for example the average of both measurements) can be chosen instead of the individual measurements. Even if the resulting value is still corrupted by an offset or noise, it can be guaranteed that they do not accumulate anywhere in the string. Thus, the measurement inaccuracies only affect the string locally and string stability can be guaranteed. However, any communication between the vehicles implies the existence of delays and the risk of communication losses, which has to be addressed in this project.

Some preliminary results on **transient scalability in undirected pinned networks** by Knorn and Ahlén (applicants) have been reported in [60]. Consider a consensus network of N agents. Consider either single integrator agents with dynamics $\dot{x}_i(t) = \sum_{j=1,j\neq i}^{N} a_{ij}(x_j(t) - x_i(t))$ or double integrator agents with dynamics $\ddot{x}_i(t) = \sum_{j=1,j\neq i}^{N} a_{ij}(x_j(t) - x_i(t)) + \sum_{j=1,j\neq i}^{n} r_{ij}(\dot{x}_j(t) - \dot{x}_i(t))$, where the coefficients a_{ij} and r_{ij} are nonzero iff a connection between agents i and j exists. It is well known that the states in such a network converge to the average of the initial conditions, that is reach consensus, if the underlying graph is connected. Connecting one or more agents to a global reference signal x_0 (referred to as "pinning") by adding the term $+\alpha_{i0}(x_0 - x_i)$ in case of single integrators or $+\alpha_{i0}(x_0(t) - x_i(t)) + \rho_{i0}(\dot{x}_0(t) - \dot{x}_i(t))$ in case of double integrators to the agents, which are connected to the reference, ensures that all agents converge to the reference signal, see for instance [32,44–47].

The results in [60] exploit the similarities between the matrix S, that describes the interconnection between the agents in the system in [56] and the transpose of the extended incidence matrix of the underlying graph. This leads to an extension of the well known Laplacian matrix L of the undirected graph, referred to as the extended Laplacian $\bar{L}$. The pinned network can then be described as a port-Hamiltonian system similar to the system description in [56]. This leads to the finding that, when allowing the disturbance vector $d(t)$ acting on the systems, the deviation between the states and their steady states at all times are bounded from above. In case of single integrators this has the form $|x(t) - \underline{1}x_0|^2 \leq |x(0) - \underline{1}x_0|^2 + \frac{\|d(\cdot)\|^2}{\min\{\alpha_{i0}, a_{ij}\}\lambda_{\min}(\bar{L})}$. In case of second order agents the bound is of a similar form, which also depends on the minimal eigenvalue of the extended Laplacian, that is $\lambda_{\min}\left(\bar{L}\right)$. It was further shown that the transients decay exponentially with a rate governed by $\lambda_{\min}\left(\bar{L}\right)$ in networks of first-order agents and with half the rate in some classes of networks of second-order agents. See [60] for details.

The results shed a different light on pinning control of networks but also on string stability for bidirectional strings. More precisely, the minimal eigenvalue of the extended Laplacian is determined by the network structure and the choice of pinned node(s). Since it has a direct impact on the transient bound and the decay rate of the transients, choosing the network structure and selecting the nodes to pin should be done such that the resulting $\lambda_{\min}\left(\bar{L}\right)$ is as big as possible. This project will aim at finding effective local algorithms for determining which nodes should be pinned to maximise $\lambda_{\min}\left(\bar{L}\right)$ and extending these results to directed networks and networks with imperfect communication.

7 National and international collaboration

We have established a well developed collaboration with several strong researchers within the proposed research area and we anticipate this collaboration to continue and grow during the course of this project. In particular, we intend to collaborate with Prof Richard Middleton at the University of Newcastle, Australia, in the field of string stability of vehicle systems, with Dr Alejandro Donaire at the University of Newcastle, Australia, and Dr Juan Carlos Agüero at the Technical University Federico Santa María (UTFSM), Valparaíso, Chile, in the field of port-Hamiltonian systems and with Prof Daniel Quevedo at the University of Paderborn, Germany, in the area of communication.

8 Independent line of research

The main applicant worked on basic problems in string stability during her time as a PhD student. Later, during her post doctoral visit at the University of Newcastle, she worked on more advanced problems together with Prof Richard Middleton, Dr Alejandro Donaire and Dr Juan Carlos Agüero. This involved the study of string stability under idealistic settings with perfect communication infrastructure. A paper, namely [59], with some preliminary results on the influence of measurement offsets was published very recently.

This research proposal is aimed to go far beyond the previous work. More precisely, the aim of the project is to address problems arising in a real world application involving communication drop-outs, quantisation, noise and sensor failures and further address transient scalability issues in networks other than simple strings or chains of agents.

9 Other grants

Prof Ahlén received a VR project grant for the period 2014–2016 entitled “Prediction of Radio Channels for Routing and Wireless Control” (Dnr:621-2013-5272). This project deals with models for wireless control purposes. Prof Dey received a VR project grant for the period 2014–2016 entitled “Networked Stochastic Estimation and Control Under Communication and Resource Constraints” (Dnr:621-2013-5395). The project investigates estimation and control algorithm design considering communication constraints and limited resources. There is no overlap between the projects listed above and the one now applied for by Dr Knorn.

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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

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	Steffi Knorn	50
2	Participating researcher	Subhrakanti Dey	15
3	Participating researcher	Anders Ahlén	15

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	2018	Total
1	Applicant	Steffi Knorn	50	400,000	400,000	400,000	1,200,000
2	Participating researcher	PhD student	70	490,000	490,000	490,000	1,470,000
	Total			890,000	890,000	890,000	2,670,000

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

Running Costs

	Running Cost	Description	2016	2017	2018	Total
1	Travel costs	Travel and guests	140,000	140,000	140,000	420,000
	Total		140,000	140,000	140,000	420,000

Depreciation costs

Depreciation cost	Description	2016	2017	2018

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	Total, applied	Other costs	Total cost
Salaries including social fees	890,000	890,000	890,000	2,670,000		2,670,000
Running costs	140,000	140,000	140,000	420,000		420,000
Depreciation costs				0		0
Premises				0		0
Subtotal	1,030,000	1,030,000	1,030,000	3,090,000	0	3,090,000
Indirect costs				0		0
Total project cost	1,030,000	1,030,000	1,030,000	3,090,000	0	3,090,000

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

The budget is based on the involvement of a post doctoral researcher, two full professors and a PhD student over a three year period. Dr Knorn (SK) is involved in both teaching and research. Professors Ahlén (AA) and Dey (SD) are both involved in administration and teaching to a level ranging between 30–50%. This project enables a strong research involvement in the proposed area.

Dr Knorn has an established collaboration with colleagues working in the proposed area in Australia, Germany and Chile. Current collaborating parties include Prof Richard Middleton and Dr Alejandro Donaire at the University of Newcastle, Australia, Prof Daniel E. Quevedo at the the University of Paderborn, Germany, and Dr Juan Carlos Agüero at the Technical Federico Santa María (UTFSM), Valparaíso, Chile. The budget includes partial funding for visits by these researchers and for the applicants' visits to Australia, Germany and Chile.

All salary figures above include social security costs (lönebikostnader) and university overhead (indirect costs). AA is already funded and will not charge the project with respect to salaries. The PhD student is expected to teach at a level of 20% per year. The nominal time for a PhD student is four years full time, or five years with 20% teaching. The PhD student will be supervised jointly by SK, AA, and SD. The funding not covered by this project will be covered by other means. The amount allocated for travel and guests will cover traveling by SK, AA and SD and contribute to cover expenses and accommodation for visitors. Taking it altogether the total cost per year for the project is 1580 KSEK of which 1030 KSEK is applied for from VR.

The required research resources needed for the project will be supplied by the Signals and Systems Division. The group has access to measurement equipment, an anechoic/EMC chamber, and a test-bed for wireless sensors, should some theoretical results need to be verified.

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

CV and publications

CV

CV for Steffi Knorn

Name: Steffi Knorn
Current Position: PostDoc in Wireless Sensor Networks
Work address: Signals and Systems, Dept. of Engineering Sciences, Uppsala University, PO Box 534, SE-75121 Uppsala, Sweden
Telephone: +46 18 471 7389
Email: steffi.knorn@signal.uu.se
URL: http://www.signal.uu.se/Staff/sk/sk.html

1. Higher education qualification

Diplom (eq. to M.Sc., with First Class Honours), Systemtechnik und technische Kybernetik (technical cybernetics), Otto-von-Guericke University Magdeburg, Germany, 2008.

2. Degree of Doctor

Ph.D., Hamilton Institute, National University of Ireland Maynooth, Ireland, 2013,
Thesis title: A Two-Dimensional Systems Stability Analysis of Vehicle Platoons
Supervisor: Prof Richard H. Middleton

3. Postdoctoral positions

January 2013 - January 2014: Research Associate, Department of Electrical and Computer Engineering, The University of Newcastle, NSW, Australia

4. Qualification required for appointment as a docent

-

5. Present position

PostDoc in Wireless Sensor Networks, Signals and Systems, Dept. of Engineering Sciences, Uppsala University, February 2014 - January 2016, percentage of research: 80%

6. Previous positions and periods of appointment

- April 2013 – June 2013: Casual Academic Lecturer at The University of Newcastle: Teaching Signal Processing
- March 2011 – December 2011: Freelance work in Maynooth, Ireland: Development, data acquisition and programming of an Apple iOS application (“Maynooth App”) Sold to the National University of Ireland Maynooth (NUIM) (It is now used as one of the main information sources for NUIM students.)
- October 2007 – March 2008: Internship at Research and Development, Daimler AG, Sindelfingen, Germany: Design, implementation and comparison of different observer strategies to detect the roll angle of passenger vehicles

7. Interruptions in research

June 2009 - May 2010 (one year): parental leave

8. Supervision

- Aarti Sheorayan, 2013, Final Year Project, The University of Newcastle, NSW, Australia, co-supervisor, project title: On-Line Tutor for Electrical Circuits
- I have started to co-supervise a PhD student in 2015.

9. Other relevant information

- Young researcher: I am currently establishing myself as a Swedish academic and as such I am hoping that the publication gradient is considered.
- Reviewer for the top international journals and conferences in control: I have reviewed several articles for IEEE Transactions on Automatic Control, Automatica, CDC, ACC, ECC etc.
- International connections: I have established a considerable international network and currently collaborate with researchers in Sweden, Germany, Australia and Chile.
- International experience: I have lived in 6 countries (Germany, Ireland, Australia, Argentina, Brazil and Sweden) and speak 6 languages.

Curriculum Vitae for Anders Ahlén

Name: Anders Ahlén
Current position: Professor in Signal Processing
Work address and Telephone: Signals and Systems, Dept. of Engineering Sciences, Uppsala University, PO Box 534, SE-75121 Uppsala, Sweden. Tel: +46 18 471 3076
e-mail and url: Anders.Ahlen@signal.uu.se ; http://www.signal.uu.se/Staff/aa/aa.html

1. Higher education qualification
Lic. Eng. (Teknologie Licentiat), Automatic Control, Uppsala University, 1984.

2. Degree of Doctor
Ph.D. (Teknologie Dr) Automatic Control, Uppsala University, Uppsala Sweden, 1986,
Thesis title: Input Estimation with Appplication to Differentiation. Supervisor: Prof Torsten Söderström.

3. Post Doctoral Positions
December 1990-December 1991; Visiting Research Fellow, Department of Electrical and Computer Engineering, The University of Newcastle, NSW, Australia.

4. Qualification required for appointment as a docent: 1990.

5. Present position
Professor (Chair) of Signal Processing and head of the Signals and Systems Division, Department of Engineering Sciences, 1996-present. Percentage of research varies from year to year, 2012-14 ~50%

6. Previous positions
January 2008-April 2008; Visiting Professor, ARC Center on Complex Dynamic Systems and Control, The University of Newcastle, NSW, Australia.
July 1996-Present; Head of the Signals and Systems Division, Uppsala University
July 1992-June 1996; Associate Professor of Signal Processing, Uppsala University.
July 1990; Associate Professor (Docent) Automatic Control, Uppsala University.
July 1984-June 1989; Assistant Professor, Automatic Control, Uppsala University.

7. Interruptions in research: N/A.

8. Supervision
Post Docs: Piyush Agrawal (April 2012-Feb 2014), Steffi Knorn (Feb. 2014--)
PhD's: 18. Sinchan Biswas, enrolled, March 2014, co-supervisor. 17. Markus Eriksson, enrolled Spetember 2013, co-supervisor. 16. Simon Bertilsson, expected PhD, June 2016, co-supervisor.
15. Rikke Apelfröjd, expected PhD: October 2016, co-supervisor. 14. Annea Barkefors, expected PhD: October 2016, co-supervisor. 13. Adrian Bahne, Multichannel Audio Signal Processing: Room Correction and Sound Perception, October 2014. (Project Manager, Dirac Research AB)
12. Daniel Aronsson, *On channel estimation and prediction for MIMO OFDM systems: Key design and performance of Kalman-based algorithms, March 2011. (MathWorks)*
11. Lars-Johan Brännmark, *Robust Sound Field Control for Audio Reproduction: A Polynomial Approach to Discrete-time Acoustic Modeling and Filter Design,* Feb. 2011.*(Chief Scientist, Dirac Research AB)*
10. Erik Björnemo, *Energy Constrained Wireless Sensor Networks: Communication Principles and Sensing Aspects*, January 2009 (Senior Researcher at Petroleum Geo-Services)
9. Mathias Johansson, *Resource Allocation under Uncertainty - Applications in Mobile Communications*, October 2004 (CEO, Dirac Research AB)
8. Nilo Casimiro Ericsson, *Revenue Maximization in Resource Allocation: Applications in Wireless Communication Networks* October 2004 (Head of Engineereing, (Prev. CEO) of Dirac Research AB)
7. Jonas Öhr, *On Anti-Windup and Control of Systems with Multiple Input Saturations: Tools, Solutions and Case Studies* , August 2003, (ABB Corporate Research, Sweden)
6. Torbjörn Ekman, *Prediction of Mobile Radio Channels: Modeling and Design*, October 2002, (Full Professor at NTNU, Norway)
5. Björn Hammarberg, *A Signal Processing Approach to Practical Neurophysiology. A Search for Improved Methods in Clinical Routine and Reseach*, April 2002, (Safegate International, Sweden)
4. Claes Tidestav, *The Multivariable Decision Feedback Equalizer Multuser Detection and Interference Rejection*, December 1999, (Ericsson Research, Sweden)
3. Erik Lindskog, *Space-Time Processing and Equalization for Wireless Communications*, May 1999, (Beceem Communications, USA)
2. Kenth Öhrn, *Design of Multivariable Cautious Discrete-time Wiener Filters: A Probabilistic Approach*, May 1996, (Bombardier Transportation, Sweden)

1. Lars Lindbom, *A Wiener Filtering Approach to the Design of Tracking Algorithms, with Applications in Mobile Radio Communications*, November 1995, (Ericsson Research)

I have also been the main advisor or co-advisor of 10 licentiate theses. Apart from the theses above I have contributed significantly to several other PhD theses at the Signals and Systems Division. Since I was appointed full professor and head of group, 20 PhD thesis (one of which has been downloaded > 22 000 times) and 18 licentiate theses have been presented. I currently advise/co-advise of 6 PhD students.

9. Additional Information: Networks in academia and industry (selected)

ABB, EU-WINNER project and the EU Network of Excellence NEWCOM, e.g., Ericsson, Nokia, etc. and several universities. In particular I would like to mention Chalmers, Göteborg, Karlstad University, KTH, Stockholm, NTNU Trondheim, The University of Newcastle, Australia, The Australian National University, University of Western Australia, University of Melbourne, North-Eastern University, USA, Politechnico di Milano, and Politechnico di Bari, Aalborg University, University of Seville, Federico Santa María Technical University, University of Paderborn, with whom I have, or have had, active collaboration, and/or for whom I have served as external reviewer of PhD theses, expert for promotions, or have exchanged PhD students. Recently I have also established connections with China, e.g., USTC, BUPT, and Southeast University. With the latter two I have, together with colleagues, had a joint VINNOVA/MOST funded research project. I have also hosted a researcher from Sony Corporation, Japan for a year, and several other researchers/PhD students from Europe, Asia, and Australia.

10. Additional Information: Entrepreneurial achievements

-2010-Present: Member of the Board of Directors, Allgotech AB.

-2010: Co-founder of Allgotech AB.

-2008: Co-founder of WISENET Holding AB.

-May 2005-Present: Chairman of the Board of Directors, Dirac Research AB.

-July 2001-2004: CEO of Dirac Research AB.

-2001: Co-founder of Dirac Research AB. A world leading company licensing state-of-the-art audio signal processing solutions to prestigeous customers such as, e.g., BMW, BMW-M, Bentley, Rolls Royce, Digital Datasat Entertainment, Pioneer, Xiaomi, Oppo, Olympus, Naim, Lear Corp., ASK, Sonic Studio, and Jays.

-Holder of 8 patents

11. Additional Information: Other Merits of relevance (selected)

-2014: Area editor for Signal Processing at the Swedish Research Council (VR)

-2010, 2011, 2012, 2013, 2014, 2015 ; (~8 weeks) Visiting Professor, ARC Center on Complex Dynamic Systems and Control, The University of Newcastle, NSW, Australia.

-2007-2013: Part of the WISENET, Vinnova Excellence Center in Wireless Sensor Networks

-2007-2008: Chairman for the evaluation committee, Signals and Systems, the Swedish Research Council

-2007: Member of the decision committee for the selection of the 20 future research leaders, a 5 year grant awarded to promising young researchers by The Foundation for Strategic Research (SSF), Sweden.

-2005: Vice Chair, technical program committee, Transmission Technology, VTC2005 Spring, Stockholm. (Responsible for the review and organization of 480 papers)

-2004: International expert for the evaluation of the Western Australian Telecom. Research Centre (WATRI) at the University of Western Australia, Perth, Australia.

-2004: Member of the evaluation committee for the Swedish Research Council.

-1998-March 2004; Editor for IEEE Transactions on Communications (Area: Signal and Modulation Design).

-July 1993-June 1999: Member of the board of The Faculty of Science and Tech., UU.

-May 2001, Winner of Business Plan Contest Venture Cup East. The competition consisted of 342 other business ideas from Swedish universities

-1987-present: Principal Investigator/Co-Investigator of some 20 research projects funded by VR, SSF, and VINNOVA and PI of an infrastructure grant from the Knut and Alice Wallenberg Foundation.

-On a regular basis: Reviewer for the top international journals and conferences in signal processing, communications, and control, evaluator of PhD (international and national) and licentiate theses, applications for university positions, research proposals, member of technical committees, chairman at international conferences, and invited talks.

CV of Prof Subhrakanti Dey (680919-1577)

Higher education degrees

1993 Master of Technology, Telecommunication Systems Engineering, Indian Institute of Technology, Kharagpur, INDIA

1991 Bachelor of Technology (Hons), Electronics & Electrical Communication Engineering, Indian Institute of Technology, Kharagpur, INDIA

Doctoral Degree

1996 PhD (Systems and Control), ``Topics in Robust Nonlinear Estimation and Control”, under the supervision of Prof John B. Moore, Dept. of Systems Eng. RSISE, The Australian National University (A.N.U), Canberra, Australia

Postdoctoral positions

1998-2000 Research Fellow, Dept. of Systems Eng. Research School of Information Sciences and Engineering (RSISE), The Australian National University, Canberra, Australia

1997-1998 Research Associate, Institute for Systems Research, University of Maryland, College Park, USA

1995-1997 Research Fellow, Dept. of Systems Eng. RSISE, The Australian National University, Canberra, Australia

Docent Level

2004, Associate Professor, The University of Melbourne, Australia

Present Position

2013- indefinite Professor in Wireless Sensor Networks, Uppsala University, Sweden, Research component 50%

Previous Positions and Periods of Appointment

2007- 2013 Full Professor, The University of Melbourne, Australia

2004-2007 Associate Professor & Reader, The University of Melbourne, Australia

2001-2003 Senior Lecturer, Dept. of Electrical & Electronic Engineering, The University of Melbourne, Australia

2000-2001 Lecturer, Dept. of Electrical & Electronic Engineering, The University of Melbourne, Australia

Interruptions in Research

Not Applicable

Supervision of Postdoctoral Researchers

2014- Dr Amirpasha Shirazina (PhD, KTH, Sweden)
2014- Dr Steffi Knorn (PhD, University of Newcastle, Australia)
2012 – 2014: Dr Mojtaba Nourian (PhD, McGill University, Canada)
2011-2013: Dr Yuan Yuan He (PhD, University of Melbourne)
2011 Dr Randa Zakhour (PhD, Eurecom, France)
2008- present: Dr Alex Leong (PhD, University of Melbourne, Australia)
2009-2011: Dr Hazer Inaltekin (PhD, Cornell University, USA)
2009-2010: Dr Vasanthan Raghavan (PhD, Univ of Wisconsin-Madison, USA)
2008-2009: Dr James Li (PhD, University of Melbourne, Australia)
2004-2006: Dr Minyi Huang (PhD, McGill University, Canada)

Supervision of PhD students

Dr Ehsan Nekouei, 2013, *Throughput Scaling Laws in Cognitive Multiple Access Networks*
Dr Athipat Limmanee, 2013, *Resource Allocation in Cognitive Radio Networks*
Dr Chih-Hong Wang, 2011, *Power Allocation for Distortion Outage Minimization in Wireless Sensor Networks*
Dr Yuan Yuan He, 2011, *Topics in Resource Optimization in Wireless Networks with Limited Feedback*
Dr Nader Ghasemi, 2011, *Networked Estimation of Hidden Markov Models under Resource Constraints*
Dr Feng Li, 2009, *Distributed Detection and Tracking in Wireless Sensor Networks*
Dr Alex Leong, 2008, *Performance of Estimation and Detection Algorithms in Wireless Networks*
Dr James (Chao-feng) Li, 2008, *Topics in Resource Allocation in Wireless Sensor Networks*
Dr John Papadriopoulos, 2007, *Resource Optimization in Multiuser Communication Networks*
Dr Antonio Galati, 2005, *Statistical Signal Processing in Sensor Networks with Applications to Fault Detection in Helicopter Transmissions*
Dr Louis Shue, 1999, *On performance analysis of state estimators for hidden Markov models*

Other Information

Publications: Authored and co-authored 2 book chapters, 68 peer reviewed journal publications (90% of which are in the IEEE Transactions, Automatica and SIAM journals) and 100 peer reviewed conference papers, and currently 5 further IEEE transactions papers under review. Prof Dey has an h-index of 21 (Google Scholar).

Research Grants: (as Principal Investigator (PI) or Chief Investigator (CI) in Australia))

Sweden:

2014-2016 "*Networked Stochastic Estimation & Control under Communication and Resource Constraints*", VR Project Grant, 2.91 M SEK, (with co-PI Prof Anders Ahlen)

Australia:

2014-2016 "*Easing the Squeeze: Dynamic and Distributed Resource Allocation with Cognitive Radio*," ARC Discovery Grant, $395,000 (with Prof J.S. Evans, Dr T. Alpcan and Dr H. Inaltekin)

2012-2014 "*Networked System Identification, Estimation and Control: Performance Optimization under Resource Constraints*", ARC Discovery Grant, $300,000 (with A/Prof Girish Nair and A/Prof Erik Weyer)

2009-2011 "*Resource aware Signal Processing and Control Algorithms for Networked Systems*", ARC Discovery Grant, $330,000 (with A/Prof Girish Nair and Dr Alex Leong (ARC APD)

2009-2012 "*Closing the Gap: Fundamental Capacity Limits for Interfering Wireless Networks and Practical Methods to Get There",* ARC Discovery Grant, $615,000 (with A/Prof S.V. Hanly, A/Prof J.S. Evans and Prof D.N.C. Tse)

2008-2013 "*Gigabit Wireless: Setting the Standard for Tomorrow's Broadband*", ARC Linkage Grant, $860,000 (with A/Prof JS Evans, A/Prof S. Hanly and Dr B Krongold) with NEC Australia

2008 "*BigNet – A Distributed Wireless Sensor Network Testbed*", ARC Linkage, Infrastructure, Equipment and Facilities Grant, $200,000 (with A/Prof M. Palaniswami et al.)

2008-2010 "*Robust Optimal Asset Liability Management via Stochastic Control Theory*", ARC Linkage Grant, $153,762 (with Dr B.La Scala, Prof I.M.Y. Mareels, Dr L. Irlicht et al) with Victorian Funds Management Corporation (VFMC), Australia

2006-2008 "*Distributed Estimation and Control under Communication Constraints",* ARC Discovery Grant, $336,000 (with A/Prof J.S. Evans and Dr G. Nair)

2003-2005 "*Fast Signal Processing and Control Algorithms for Complex Hierarchical Systems*", ARC Discovery Grant, $180,075 (with Dr J.S. Evans)

2003-2005 "*Towards an Information Theory for Communication-Limited Control Systems*", ARC Discovery Grant, $157,213 (with Dr G. Nair and Prof R.J. Evans)

Additional Information: Prof Dey was a Full Professor at the University of Melbourne, Australia before joining Uppsala University as a Professor in 2013. During his time at University of Melbourne, Prof Dey obtained (as a *Chief Investigator*) a total of approximately 3.6 million AUD in research grants from the Australian Research Council (ARC) in 7 Discovery Projects, and 2 Linkage projects (involving industry partners such as NEC Australia and Victorian Funds Management Corporation, Australia), during 2002-2012. He has also been a Research project leader in the *ARC funded Special Research Centre on Ultra-Broadband Information Networks* during 2002-2008, which enjoyed a total funding of 5.2 million AUD in 9 years. He also made significant contributions towards *National ICT Australia (NICTA) Victoria Research Labs* during 2003-2005 and the *Cooperative Research Centre on Robust and Adaptive Systems* at Canberra, A.N.U. during 1994-1996. He has been involved with several industry related projects in Australia and USA.

Professional Activities:

2014- Associate Editor, *IEEE Transactions on Signal Processing*

2014- Chair, Stochastic Systems Technical Committee, IFAC

2012 Member of the Peer Review Committee, *Excellence in Research for Australia (ERA) initiative*

2012 Guest Editor, *EURASIP Journal of Wireless Communications and Networking Special Issue on Recent Advances in Optimization Techniques for Wireless Communication Networks*

2009- Vice Chair, Stochastic Systems Technical Committee, IFAC

2006-2010 Associate Editor, *IEEE Transactions on Signal Processing*

2004-2008 Associate Editor, *IEEE Transactions on Automatic Control*

2003 - present Associate Editor, *Systems & Control Letters* (Elsevier)

2000-2011 Technical Program Committee member for major IEEE conferences such as IEEE *Globecom 2007, 2008, 2009, 2010, 2014, WCNC 2008, 2009,2010,2011, 2012, 2013, 2014 and ICC 2011, and also IFAC World Congress 2011, 2014, IFAC NecSys Workshop 2012,2013, RAWNET 2012,2013,2014 and PIMRC 2012,2013, 2014, SSP 2014, VTC Spring 2014, GlobalSIP 2014,* to name a few.

2002 -2012 Assessor for ARC Grants & Fellowships

2006- Senior Member, IEEE

Publication list

List of Publications by Steffi Knorn, 2008-2015

Citations by Google Scholar

1. Peer-reviewed original articles in journals

1.1 S. Knorn, S. Dey, A. Ahlén and D.E. Quevedo (2015),
Distortion Minimization in Multi-Sensor Estimation Using Energy Harvesting and Energy Sharing,
IEEE Transactions on Signal Processing, vol. x, no. x, pp. 1-15, to appear,
Number of citations: N/A.

1.2 * S. Knorn, A. Donaire, J.C. Agüero and R.H. Middleton (2014),
Passivity-based Control for Multi-Vehicle Systems Subject to String Constraints,
Automatica, vol. 50, no. 12, pp. 3224–3230, December 2014,
Number of citations: -.

1.3 * S. Knorn and R.H. Middleton (2013),
Stability of Two-Dimensional Linear Systems with Singularities on the Stability Boundary using LMIs,
IEEE Transactions on Automatic Control, vol. 58, no. 10, pp. 2579-2590, October 2013,
Number of citations: 14.

1.4 R. Shorten, M. Corless, K. Wulff, S. Klinge (maiden name), and R.H. Middleton (2009),
Quadratic Stability and Singular SISO Switching Systems,
IEEE Transactions on Automatic Control, vol. 54, no. 11, pp. 2714-2718, November 2009,
Number of citations: 30.

1.5 S. Knorn, and R.H. Middleton (2015),
Asymptotic Stability of Nonlinear Two-Dimensional Continuous-Discrete Roesser Models,
Under review for IEEE Transactions on Automatic Control.
See also http://www.steffi-knorn.de/wp-uploads/knorn2015c.pdf

1.6 * S. Knorn, A. Donaire, J.C. Agüero and R.H. Middleton (2015),
Scalability of Bidirectional Vehicle Strings with Static and Dynamic Measurement Errors,
Under review for Automatica.
See also http://www.steffi-knorn.de/wp-uploads/knorn2015b.pdf

1.7 * S. Knorn, and A. Ahlén (2014),
Transient Scalability in Multi Agent Systems Described by Undirected Graphs,
Under review for Automatica.
See also http://www.steffi-knorn.de/wp-uploads/knorn2014e.pdf

1.8 S. Knorn, and R.H. Middleton (2014),
Exponential Stability of Nonlinear Two-Dimensional Roesser Models,
Under review for IEEE Transactions on Automatic Control.
See also http://www.steffi-knorn.de/wp-uploads/knorn2014d.pdf

2. Peer-reviewed conference contributions

2.1 S. Knorn, S. Dey, A. Ahlén and D.E. Quevedo (2015),
Multi-Sensor Estimation Using Energy Harvesting and Energy Sharing,
IEEE International Conference on Communications, June 2015,
Number of citations: N/A.

2.2 S. Knorn, and R.H. Middleton (2014),
Lymph compartment models and HIV intra patient infection dynamics,
IEEE Conference on Control Applications, pp. 1699–1704, October 2014,
Number of citations: -.

2.3 * S. Knorn, A. Donaire, J.C. Agüero and R.H. Middleton (2014),
Scalability of Bidirectional Vehicle Strings with Measurement Errors,
IFAC World Congress, pp. 9171–9176, August 2014,
Number of citations: 1.

2.4 S. Knorn and R.H. Middleton (2013),
Two-Dimensional Analysis of String Stability of Nonlinear Vehicle Strings,
52nd IEEE Conference on Decision and Control, pp. 5864-5869, December 2013,
Number of citations: 2.

2.5 S. Knorn, A. Donaire, J.C. Agüero and R.H. Middleton (2013),
Energy-based Control of Bidirectional Vehicle Strings,
3rd Australian Control Conference, pp. 251-256, November 2013,
Number of citations: 3.

2.6 S. Knorn and R.H. Middleton (2013),
String Stability Analysis of a Vehicle Platoon with Communication Range 2 Using the Two-Dimensional Induced Operator Norm,
Proceeding of the European Control Conference, pp. 3354-3359, July 2013,
Number of citations: 1.

2.7 S. Knorn and R.H. Middleton (2012),
Asymptotic Stability of Two-Dimensional Continuous Roesser Models with Singularities at the Stability Boundary,
51st IEEE Conference on Decision and Control, pp. 7787-7792, December 2012,
Number of citations: -.

2.8 S. Knorn and R.H. Middleton (2012),
Two-Dimensional Frequency Domain Analysis of String Stability,
2nd Australian Control Conference, pp. 301-306, November 2012,
Winner of Best Student Paper Award,
Number of citations: 1.

2.9 S. Klinge (maiden name) and R.H. Middleton (2009),
Time Headway Requirements for String Stability of Homogeneous Linear Unidirectionally Connected Systems,
Joint 48th IEEE Conference on Decision and Control and 28th Chinese Control Conference, pp. 1992-1997, December 2009,
Number of citations: 24.

2.10 S. Klinge (maiden name) and R.H. Middleton (2009),
String Stability Analysis of Homogeneous Linear Unidirectionally Connected Systems with Nonzero Initial Conditions,
IET Irish Signals and Systems Conference, June 2009,
Number of citations: 8.

2.11 R. Shorten, M. Corless, R.H. Middleton, S. Klinge (maiden name), and K. Wulff (2009),

A Quadratic Stability Result for Singular Switched Systems with Application to Anti-Windup Control,
Proceedings of the 2009 American Control Conference, pp. 1917-1922, June 2009,
Number of citations: 6.

2.12 L. Grigorov, K. Rudie, J.E.R. Cury and S. Klinge (maiden name) (2008),
Template Design and Automatic Generation of Controllers for Industrial Robots,
Proceedings of the 2008 ACM Symposium on Applied Computing, March 2008,
Number of citations: 1.

2.13 S. Knorn and S. Dey (2015),
Optimal Sensor Transmission Energy Allocation for Linear Control Over a Packet Dropping Link with Energy Harvesting,
Under review for the IEEE Conference on Decision and Control, December 2015.

4. Research review articles

4.1 S. Knorn, Z. Chen and R.H. Middleton (2014),
Overview: Collective Control of Multi-agent Systems,
Under review for IEEE Transactions on Control of Network Systems.
See also http://www.steffi-knorn.de/wp-uploads/knorn2014c.pdf

9. Most cited journal and conference publications

9.1 R. Shorten, M. Corless, K. Wulff, S. Klinge (maiden name), and R.H. Middleton (2009),
Quadratic Stability and Singular SISO Switching Systems,
IEEE Transactions on Automatic Control, vol. 54, no. 11, pp. 2714-2718, November 2009,
Number of citations: 30.

9.2 S. Klinge (maiden name) and R.H. Middleton (2009),
Time Headway Requirements for String Stability of Homogeneous Linear Unidirectionally Connected Systems,
Joint 48th IEEE Conference on Decision and Control and 28th Chinese Control Conference, pp. 1992-1997, December 2009,
Number of citations: 24.

9.3 * S. Knorn and R.H. Middleton (2013),
Stability of Two-Dimensional Linear Systems with Singularities on the Stability Boundary using LMIs,
IEEE Transactions on Automatic Control, Vol. 58, No. 10, pp. 2579-2590, October 2013,
Number of citations: 14.

9.4 S. Klinge (maiden name) and R.H. Middleton (2009),
String Stability Analysis of Homogeneous Linear Unidirectionally Connected Systems with Nonzero Initial Conditions,
IET Irish Signals and Systems Conference, June 2009, Number of citations: 8.

9.5 R. Shorten, M. Corless, R.H. Middleton, S. Klinge (maiden name), and K. Wulff (2009),
A Quadratic Stability Result for Singular Switched Systems with Application to Anti-Windup Control,
Proceedings of the 2009 American Control Conference, pp. 1917-1922, June 2009,
Number of citations: 6.

LIST OF PUBLICATIONS, 2007 - 2014

Anders Ahlén, March 2015

Citations by Google Scholar

1. Peer-reviewed original articles

1.1 M. Sternad, T. Svensson, T. Ottosson, A. Ahlén, A. Svensson and A. Brunström (2007)
Towards systems beyond 3G based on adaptive OFDMA transmission.
Processings of the IEEE, vol. 95, no. 12, pp. 2432-2455, December 2007. Number of citations: 117.

1.2 L-J. Brännmark and A. Ahlén (2009)
Spatially Robust Audio Compensation Based on SIMO Feedforward Control.
IEEE Transactions on Signal Processing, no 4, vol. 5, 2009. Number of citations: 16.

1.3 D. E. Quevedo, A. Ahlén, and J. Østergaard (2010)
Energy Efficient State Estimation With Wireless Sensors Through the Use of Predictive Power Control and Coding.
IEEE Transactions on Signal Processing, Vol. 58, No9, pp. 4811-4823, 2010. Number of citations: 44.

1.4 D. E. Quevedo, A. Ahlén, A. S. Leong, and S. Dey (2012)
On Kalman Filtering Over Fading Wireless Channels With Controlled Transmission Powers.
Automatica, Vol 48, no7, pp 1306-1316, July 2012. Number of citations: 40.

1.5 * D. E. Quevedo, A. Ahlén, and K. H. Johansson (2013)
State Estimation Over Sensor Networks With Correlated Wireless Channels.
IEEE Transactions on Automatic Control. Vol. 58, No. 3, pp. 581-593, March 2013. Number of citations: 24.

1.6 L-J. Brännmark, A. Bahne and A. Ahlén (2013)
Compensation of Loudspeaker-Room Responses in a Robust MIMO Control Framework.
IEEE Transactions on Audio, Speech, and Language Processing. Vol. 21, No.6, pp. 1201-1216, June 2013. Number of citations: 8.

1.7 D. E. Quevedo, K. H. Johansson, A. Ahlén, I. Jurado (2013)
Adaptive Controller Placement for Wireless Sensor-Actuator Networks with Erasure Channels,
Automatica. Vol. 49, pp. 3458-3466. Number of citations: 5.

1.8 A. Bahne, L-J. Brännmark, and A. Ahlén (2013)
Pairwise Channel Similarity in Loudspeaker–Room Equalization.
IEEE Transactions on Signal Processing. Vol. 22, No 2, pp. 6276-6290, December 15, 2013. Number of citations: N/A.

1.9 D. E. Quevedo, J. Østergaard, and A. Ahlén (2014)
A Power Control and Coding Formulation for State Estimation with Wireless Sensors,
IEEE Transactions on Control Systems Technology. Vol. 22, No 2, pp. 413-427, March 2014. Number of citations: 6.

1.10 * P. Agrawal, A. Ahlén, T. Olofsson, and M. Gidlund (2014)
Long Term Channel Characterization for Energy Efficient Transmission in Industrial Environments.
IEEE Transactions on Communications, vol 62, no. 8, pp 3004-3014, 2014. Number of citations: N/A.

1.11 M. Nourian, S. Dey, and A. Ahlén (2014)
Distortion Minimization in Multi-Sensor Estimation with Energy Harvesting.
IEEE Journal of Selected Areas in Communications. To Appear. Number of citations: N/A.

1.12 L. J. Brännmark, and, A. Ahlén (2015)
Multichannel Room Correction with Focus Control..
Journal of the Audio Engineering Society, Special Issue on Spatial Audio, vol. 63, no. 1/2, pp. 21-30, January/February 2015. Number of citations: N/A.

1.13 S. Knorn, S. Dey, A. Ahlén, and D. E. Quevedo (2015)
Multi-Sensor Estimation Using Energy Harvesting and Energy Sharing.
IEEE Transactions on Signal Processing, vol x. pp 1-15. To appear.

1.14 A. S. Leong, D. E. Quevedo, A. Ahlén, and K. H. Johansson (2015)
Network Topology Reconfiguration for State Estimation Over Sensor Networks With Correlated Packet Drops.
Under review for *IEEE Transactions on Automatic Control*. See also http://www.signal.uu.se/Staff/aa/rev-TAC.pdf

1.15 A. Bahne, and A. Ahlén (2015)
Personal Multichannel Spatial Audio.
Under review for *IEEE Transactions on Audio Speech and Language Processing*. See also http://www.signal.uu.se/Staff/aa/rev-TSLP2.pdf

1.16 S. Knorn, and A. Ahlén (2015)
Transient Scalability in MultiAgent Systems Described by Undirected Graphs.
Under review for *Automatica*. See also http://www.signal.uu.se/Staff/aa/rev-Automatica1.pdf

1.17 * T. Olofsson, A. Ahlén, and M. Gidlund (2015)
Modeling of Wireless Sensor Network Channels in Industrial Environments.
Under review for *IEEE Transactions on Signal Processing*. See also http://www.signal.uu.se/Staff/aa/rev-TSP3.pdf

2. Peer-reviewed conference contributions)

2.1 E. Björnemo, , M. Johansson and A. Ahlén (2007)
Two hops is one too many in an energy-limited wireless sensor network. *IEEE International Conference on Acoustics, Speech and Signal Processing.*, Honolulu, Hawaii, May 2007. Number of citations: 13.

2.2 M. Johansson, E. Björnemo and A. Ahlén (2007)
Fixed link margins outperform power control in energy-limited wireless sensor networks. *IEEE International Conference on Acoustics, Speech and Signal Processing.*, Honolulu, Hawaii, May 2007. Number of citations: 10.

2.3 E. Björnemo, A. Ahlén and M. Johansson (2007)
On the energy efficiency of cooperative MIMO in Nakagami fading wireless sensor networks . *Asilomar Conferences on Signals, Systems, and Computers.*, Asilomar, California, July 2007. (Invited paper). Number of citations: 6.

2.4 A. Ahlén, B. Ahlgren, R. Grnros, P. Gunningberg, K. Hjort, I. Katardjiev, C. Rohner and A. Rydberg (2008)
Robust loudspeaker equalization based on position-independent excess phase modeling. *Presentation of the VINN Excellence Center for Wireless Sensor Networks (WISENET).*, *Conference on Radio Science (RVK08)*, Växjö, Sweden, June 2008

2.5 L-J. Brännmark, and A. Ahlén (2008)
Robust loudspeaker equalization based on position-independent excess phase modeling. *IEEE International Conference on Acoustics, Speech and Signal Processing.*, Las Vegas, Nevada, April 2008. Number of citations: 4.

2.6 D. E. Quevedo, and A. Ahlén (2008)
A predictive power control scheme for energy efficient state estimation via wireless sensor networks. *IEEE Conference on Decision and Control.*, Cancún, Mexico, December 2008. Number of citations: 11.

2.7 D. E. Quevedo, A. Ahlén, and G. C. Goodwin (2008)
Predictive Power Control of Wireless Sensor Networks for Closed Loop Control. *International Workshop on Assessment and Future Directions of Non-Linear Model Predictive Control*, Pavia, Italy, September 2008. Number of citations: 5.

2.8 J. Østergaard, D. E. Quevedo, and A. Ahlén (2009)
Predictive Power Control and Multiple Description Coding for Wireless Sensor Networks. *IEEE International Conference on Acoustics, Speech and Signal Processing.*, Taipei, Taiwan, April 2009. Number of citations: 2.

2.9 D. E. Quevedo, A. Ahlén, J. Østergaard and G. C. Goodwin (2009)
Innovation based state estimation with wireless sensor networks. *European Control Conference, (ECC'09).*, Budapest, Hungary, August 2009. Number of citations: 1.

2.10 L-J. Brännmark and A. Ahlén (2009)
Variable Control of the Pre-Response Error in Mixed Phase Audio Precompensation. *2009 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA 2009)*. Oct. 2009 New York City, NY. Number of citations: 1.

2.11 J. Østergaard, D. E. Quevedo, and A. Ahlén (2010)
Predictive Power Control For Dynamic State Estimation Over Wireless Sensor Networks With Relays. *Eusipco 2010*, 23-27 August 2010, Aalborg, Denmark. Number of citations: 3.

2.12 D. E. Quevedo, A. Ahlén, A. S. Leong, and S. Dey (2011)
On Kalman Filtering with Fading Wireless Channels Goverened by Power Control. *18th IFAC World Congress*, Milano, Italy, August 28 - September 2, 2011. Number of citations: 2.

2.13 * D. E. Quevedo, A. Ahlén and K. H. Johansson (2011)
Stability of State Estimation over Sensor Networks with Markovian Fading Channels. *18th IFAC World Congress*, Milano, Italy, August 28 - September 2, 2011. Number of citations: 11.

2.14 O. Eriksson, E. Björnemo, A. Ahlén and M. Gidlund (2011)
On Hybrid ARQ Adaptive Forward Error Correction in Wireless Sensor Networks. *37th Annual Conference of the IEEE Industrial Electronics Society*, Melbourne, Australia, November 7 - November 11, 2011. Number of citations: 3.

2.15 L-J. Brännmark, A. Bahne and A. Ahlén (2012)
Improved Loudspeaker-Room Equalization Using Multiple Loudspeakers and MIMO Feedforward Control. *IEEE International Conference on Acoustics, Speech and Signal Processing, ICASSP 2012*, Kyoto, Japan, March 2012. Number of citations: 2.

2.16 A. Bahne, L-J. Brännmark, and A. Ahlén (2012)
Improved Loudspeaker-Room Equalization for Stereo Systems Regarding Channel Similarity. *IEEE/IET International Conference on Audio, Language and Image Processing, ICALIP2012*, Shanghai, China, July 2012. Number of citations: 1.

2.17 D. E. Quevedo, K. H. Johansson, A. Ahlén and I. Jurado (2012)
Dynamic Controller Allocation for Control over Erasure Channels. *3rd IFAC Workshop on Distributed Estimation and Control in Networked Systems*, Santa Barbara, USA, September 2012. Number of citations:5.

2.18 A. Limmanee, S. Dey, and A. Ahlén (2013)
Distortion Minimization via Multiple Sensors under Energy Harvesting Constraints. *SPAWC 2013*. Number of citations: 1.

2.19 * P. Agrawal, A. Ahlén, T. Olofsson, and M. Gidlund (2014)
Characterization of Long Term Channel Variations in Industrial Wireless Sensor Networks. *International Conference on Communications (ICC), Sydney, Australia, June 2014.*

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1. E. Nekouei, H. Inaltekin and S. Dey, “Capacity Scaling Limits of Cognitive Multiple Access Networks," in *Mechanisms and Games for Dynamic Spectrum Access*, (Editors: T. Alpcan, H. Boche, M. L. Honig and H.V. Poor), pp. 304-332, Cambridge University Press, Cambridge, UK, 2014.

FIVE MOST CITED publications (citation data from Google Scholar)

1. M. Huang and S. Dey, “Stability of Kalman filtering with Markovian packet losses”, *Automatica*, vol. 43, no. 4, pp. 598-607, April 2007. [*Number of Citations: 267*]
2. P. Minero, M. Franceschetti, S. Dey and G. Nair, “Data Rate Theorem for Stabilization over Time-Varying Feedback Channels,” *IEEE Transactions on Automatic Control*, vol. 54, no. 2, pp. 243-255, February 2009. [*Number of Citations:*] [*Number of Citations: 123*]
3. * T. Alpcan, T. Basar and S. Dey, "A Power Control Game Based on Outage Probabilities for Multicell Wireless Data Networks", *IEEE Transactions on Wireless Communications*, vol. 5, no. 4, pp. 890-899, April 2006. [*Number of Citations: 111*]

4. * J. Papandriopoulos, S. Dey and J.S. Evans, “Optimal and Distributed Protocols for Cross-Layer Design of Physical and Transport Layers in MANETs,” *IEEE/ACM Transactions of Networking*, vol. 16, no. 6, pp. 1392-1405, December 2008. [*Number of Citations: 96*]
5. * J. Papandriopoulos, J.S. Evans and S. Dey, “Optimal power control for Rayleigh-faded multiuser systems with outage constraints,” *IEEE Transactions on Wireless Communications*, volume 4, no. 6, pp. 2705-2715, November 2005. [*Number of Citations: 69*]

CV

Name: Steffi Knorn	**Doctorial degree:** 2013-09-12
Birthdate: 19840130	**Academic title:** Doktor
Gender: Female	**Employer:** No current employer

Research education

Dissertation title (swe)

Dissertation title (en)

A Two-Dimensional Systems Stability Analysis of Vehicle Platoons

Organisation	Unit	Supervisor
National University of Ireland Maynooth, Ireland Not Sweden - Higher Education institutes	Hamilton Institute	Richard H. Middleton

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20202. Reglerteknik		2013-09-12

CV

Name: Subhrakanti Dey	**Doctorial degree:** 1996-04-23
Birthdate: 19680919	**Academic title:** Professor
Gender: Male	**Employer:** Uppsala universitet

Research education

Dissertation title (swe)

Dissertation title (en)

Topics in Robust Nonlinear Estimation and Control

Organisation	Unit	Supervisor
Australian National University, Australia Not Sweden - Higher Education institutes	Research School of Information Sciences and Engineering	John Moore

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20202. Reglerteknik		1996-04-23

CV

Name: Anders Ahlén	**Doctorial degree:** 1986-05-16
Birthdate: 19531117	**Academic title:** Professor
Gender: Male	**Employer:** Uppsala universitet

Research education

Dissertation title (swe)

Input Estimation with Application to Differentiation

Dissertation title (en)

Input Estimation With Application to Differentiation

Organisation	Unit	Supervisor
Uppsala universitet, Sweden Sweden - Higher education Institutes	Inst för teknikvetenskaper	Torsten Söderström

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20202. Reglerteknik	ISBN 91-554-1850-3	1986-05-16

Publications

Name: Steffi Knorn	**Doctorial degree:** 2013-09-12
Birthdate: 19840130	**Academic title:** Doktor
Gender: Female	**Employer:** No current employer

Knorn, Steffi has not added any publications to the application.

Publications

Name: Subhrakanti Dey	**Doctorial degree:** 1996-04-23
Birthdate: 19680919	**Academic title:** Professor
Gender: Male	**Employer:** Uppsala universitet

Dey, Subhrakanti has not added any publications to the application.

Publications

Name: Anders Ahlén	**Doctorial degree:** 1986-05-16
Birthdate: 19531117	**Academic title:** Professor
Gender: Male	**Employer:** Uppsala universitet

Ahlén, Anders 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.