Vetenskapsrådet

Application

2015-03-31

2015-05381	**Vazquez, Carlos**	**NT-14**

Information about applicant

Name: Carlos Vazquez

Doctorial degree: 2010-09-29

Birthdate: 19800219

Academic title: Doktor

Gender: Male

Employer: Umeå universitet

Administrating organisation: Umeå universitet

Project site: Institutionen för tillämpad fysik och elektronik+

Information about application

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

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Focus: Unga forskare

Subject area:

Project title (english): Resilient control design for superior performance and application to underactuated robotics and mobile hydraulics.

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Project end: 2017-12-31

Review panel applied for: NT-14, NT-13, NT-16

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Keywords: Resilient control design, Lyapunov Methods, Underactuated systems

Funds applied for

Year:	2016	2017
Amount:	944,891	969,843

Descriptive data

Project info

Project title (Swedish)*

Resilient kontroll design för överlägsen prestanda och tillämpning på underaktuerade robotteknik och mobil hydraulik.

Project title (English)*

Resilient control design for superior performance and application to underactuated robotics and mobile hydraulics.

Abstract (English)*

The next generation of control systems solutions requires a high level of reliability and resilience under the presence of external perturbations, uncertainties and failures. In this context, one of the main goals of this project is the development of resilient control algorithms where the control effort should be able to react, compensate and maintain the desired performance in complex scenarios. This includes emerging areas in control and robotics as well as industrial applications where the environment and operation conditions are not always propitious, and perturbations and failures are part of the everyday life. Additionally, an acceptable performance under noise and uncertainty in measurements as well as in communications channels should be guaranteed.
One of the objectives of the proposed project is to develop resilient control/observation algorithms for emerging complex tasks in robotics. The study will be supported by the Lyapunov analysis and it will exploit the Partial Stability approach, vector and discontinuous Lyapunov functions. The project will continue for two years covering three main activities: Design of new resilient control algorithms for multi-input multi-output nonlinear systems, design of robust methods for observation and differentiation under noise and uncertainty in measurements as well as in communications channels and new advanced motion control design applications including underactuated robotics and mobile hydraulics.
Because of the importance of industrial robotics, where the creation of resilient solutions is of great value, we think this problem needs to be further investigated. Moreover, this proposal give a step forward to obtain a better understanding of the related phenomena. On the other hand the extension of the method of Lyapunov functions, including the partial stability approach, discontinuous and vector Lyapunov functions, to the class of multi-input multi-output systems is very important from a practical point of view, since it can offer valuable information to the control designer, opening new possibilities in different fields of control systems and underactuated robotics.

Popular scientific description (Swedish)*

Nästa generation av styrsystem lösningar kräver en hög grad av tillförlitlighet och motståndskraft under närvaro av externa störningar, osäkerhet och misslyckanden. I detta sammanhang är en av de viktigaste målen för detta projekt att utveckla fjädrande styralgoritmer där styr ansträngningar bör kunna reagera, kompensera och upprätthålla den önskade prestanda i komplexa scenarier. Detta inkluderar framväxande områden inom kontroll och robotik samt industriella tillämpningar där miljö- och driftsförhållanden inte alltid gynnsamma och störningar och misslyckanden är en del av vardagen. Dessutom bör en acceptabel prestanda under väsen och osäkerhet i mätningar samt i kommunikationskanaler garanteras och detta förslag ger ett steg framåt för att få en bättre förståelse av de relaterade fenomen. Den fjädrande styrning / observation designen är relaterade med tre viktigaste egenskaperna: ändligt-tidskonvergens, exponentiellt värde och slutlig boundedness. Dessa problem kan hanteras av lyapunovfunktioner metoder. Däremot är design av strikta Lyapunovfunktioner inte en enkel uppgift där ofta lämplig utformning innefattar icke-släta, icke-Lipschitz eller ens diskontinuerliga Lyapunovfunktioner. Förlängningen av metoden för lyapunovfunktioner, inklusive den partiella synsätt stabilitet, diskontinuerliga och vektor Lyapunovfunktioner, den klass av multi-input multi-output system är också viktigt ur praktisk synvinkel, eftersom den kan ge värdefull information till kontroll formgivare, öppnar nya möjligheter inom olika områden av styrsystem och underaktuerade robotik.

Project period

Number of project years*

2

Calculated project time*

2016-01-01 - 2017-12-31

Deductible time

Deductible time

Cause	Months

Career age: 54

Career age is a description of the time from your first doctoral degree until the last day of the call. Your career age change if you have deductible time. Your career age is shown in months. For some calls there are restrictions in the career age.

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 > 20201. Robotteknik och automation 1. Naturvetenskap > 102. Data- och informationsvetenskap (Datateknik) > 10202. Systemvetenskap, informationssystem och informatik (samhällsvetenskaplig inriktning under 50804)

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

Keyword 1*

Resilient control design

Keyword 2*

Lyapunov Methods

Keyword 3*

Underactuated systems

Keyword 4

Keyword 5

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*

The research does not raise any ethical issues

The project includes handling of personal data

No

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

Resilient control design for superior performance and application to underactuated robotics and mobile hydraulics.

Carlos Vázquez.

March 30, 2015

Abstract

The next generation of control systems solutions requires a high level of reliability and resilience under the presence of external perturbations, uncertainties and failures. In this context, one of the main goals of this project is the development of resilient control algorithms where the control effort should be able to react, compensate and maintain the desired performance in complex scenarios. This includes emerging areas in control and robotics as well as industrial applications where the environment and operation conditions are not always propitious, and perturbations and failures are part of the everyday life.

Expected outcomes of the project are:

- Resilient control algorithms for multi-input multi-output nonlinear systems.
- Robust methods for observation and differentiation under noise and uncertainty in measurements as well as in communications channels.
- New advanced motion control design applications for underactuated systems, industrial forestry cranes and tractor front loaders.

1 Introduction

The design of control laws under the presence of heavy uncertainty conditions is one of the main problems of modern control theory, including noise and uncertainty in measurements as well as in communications channels. In this context, the strict stability analysis is usually related to three specific properties: finite-time convergence, exponential rate and ultimate boundedness. These problems can be handled by Lyapunov functions methods. However, the design of strict Lyapunov functions is not a simple task where frequently the appropriate design includes non-smooth, non-Lipschitz or even discontinuous Lyapunov functions.

To analyze asymptotic stability of the origin, it is sufficient to find a continuous positive definite function $V(\cdot)$ such that for any trajectory of the system the function V is monotonically decreasing. The case were the function $V(\cdot)$ is continuously differentiable has been widely studied in literature, see [21]. Recently, in [38] and [37], some results concerning the case when $V(\cdot)$ is discontinuous have been pointed out. But in general, the non-smooth case remain still open.

On the other hand, the partial stability approach and vector Lyapunov function method offers a very flexible mechanism since each function can satisfy less rigid requirements, see [4], [24], [33], [55] and [56]. Due to the fact that a given large system may be decomposed into interconnected subsystems to determine the stability of the system from the stability properties of the subsystems and the nature of the interconnections, in some situations several Lyapunov functions result naturally and employing more Lyapunov functions yields better results. In other cases, it is convenient to pose a *partial stability* problem, see [55] and [56].

2 Purpose and aims.

The objective of the proposed project is to develop resilient control/observation algorithms for emerging complex tasks in robotics. New tasks in robotics require higher precision over complex scenarios where the active compensation of matched and unmatched perturbations is required. In addition, not all the states are available for measurement, the design of robust differentiators and observers should be considered. The study will be supported by the Lyapunov analysis and it will exploit the Partial Stability approach, vector and discontinuous Lyapunov functions. In summary, the project consider the following points:

a) Design of resilient control methods under complex scenarios including perturbations, parametric variations and failures.

b) Design of differentiator/observers under noise and uncertainty in measurements as well as in communications channels.

c) Methodology of design based on *strict* Lyapunov functions, including the Partial Stability approach, Vector and Discontinuous Lyapunov functions.

d) Application to underactued robotics and mobile hydraulics.

3 Survey of the field.

Resilient control design can be posed in the context of uniform stabilization of dynamical systems in the presence of uncertain bounded inputs, see [43]. By uniformity in this context we understand invariance (exact or approximate) of the closed-loop system with respect to disturbing inputs (disturbance rejection or cancellation are another names of that problem). Many different solutions for ε-invariant stabilization have been proposed: time delay control [57], active disturbance rejection [19], universal integral controls [23, 17], various sliding-mode control algorithms [27, 14] converging in a finite time, model-free control [16] (just to mention a few, there are also many other adaptive/fuzzy/neural control solutions). However, most of the cases these solutions are restricted to the single-input single-output case. Recently, some approaches to the multi-input multi output case have been presented in [30] and [31], but the general case remains still open.

On the other hand, in order to compensate matched perturbations, sliding mode techniques have been shown to be robust and easy to implement, see [45], [25]. However, when unmatched perturbations are present, the appropriate sliding mode enforcement is an open challenge. In order to deal with unmatched perturbations, different robust schemes in combination with sliding mode have been applied. For example, based on high order sliding mode observers, an identification strategy was proposed in [13]. In [12] a hierarchical control method is presented. Recently, in [9] a backstepping technique with sliding mode observation is implemented.

High-gain observers, see [22], and *high order sliding mode differentiators* have shown a very good performance even in the presence of noise, see [28]. Basically, the key breakthrough has appeared in the work by Levant, see [26], where a robust first order exact differentiator using a second order sliding mode technique, known as *super-twisting algorithm (ST)*, is introduced. Based on ST an observer for mechanical systems was introduced in [10]. In order to estimated the convergence time, in the work of [34] and [39] a non-smooth Lyapunov approach was introduced. One of the main difficulties is the selection of the gains: If a global constant bound is chosen for the whole practical operation region, the constant would be excessively large that would result in increasing errors. Some ideas of how to include a time varying gains in the design have been given in [29]; however, no suggestions on choosing such gains for control systems, or the enhancement/tuning of the parameters under the presence of noise have being given.

4 Significance.

Because of the importance of industrial robotics, where the creation of resilient solutions is of great value, we think this problem needs to be further investigated. The main theoretical contribution of this proposal is concerned to the creation of new resilient control algorithms for multi-input multi output nonlinear systems and providing an acceptable performance under noise and uncertainty in measurements as well as in communications channels. We believe that this proposal give a step forward to obtain a better understanding of the related phenomena.

On the other hand the extension of the method of Lyapunov functions, including the partial stability approach, discontinuous and vector Lyapunov functions, to the class of multi-input multi-output systems is very important from a practical point of view, since it can offer valuable information to the control designer, opening new possibilities in different fields of control systems and underactuated robotics.

5 Project description.

The statement of ε-invariant control design problem can be given following a recent development [16]. Consider a SISO uncertain nonlinear system, which model is given in the implicit form (it is not resolved with respect to the highest derivative):

$$f[y(t), \dot{y}(t), \ldots, y^{(n)}(t), u(t), d(t)] = 0,\ t \geq 0,$$

where $y(t) \in \mathbb{R}$ is the measured output, $u(t) \in \mathbb{R}$ is the control input, $d(t) \in \mathbb{R}^m$ is the vector of uncertain parameters/signals, $n \geq 1$ is the system dimension, which may be unknown, $f : \mathbb{R}^{n+m+1} \to \mathbb{R}$ is an unknown nonlinear function ensuring existence of the system solutions at least locally. Fixing $k \geq 1$, a local model can be extracted:

$$y^{(k)}(t) = u(t) + F(t),$$

where $F(t) \in \mathbb{R}$ is a new unknown input including $y, y^{(1)}, \ldots, y^{(n)}$, u and d. This model may have sense only locally, but under assumption that the dynamics of $y^{(k+1)}, \ldots, y^{(n)}$ are stable (*i.e.* the system is minimum phase with relative degree k [23, 16]) the original stabilization problem for uncertain nonlinear system can be reduced to uniform (ε-invariant) stabilization of a chain of k integrators subjected by unknown matched input F. Frequently, some assumptions that F is bounded and it has a bounded derivative (at least locally) are additionally imposed.

There are many solutions to this problem, which are based on the idea that if it is possible to estimate

$y^{(k)}(t)$ then $F(t) = y^{(k)}(t) - u(t)$ can be evaluated and compensated by the control. The difference is mainly in the tools used for estimation of $y^{(k)}(t)$ (high-gain linear observers in [23, 17], sliding-mode differentiators in [27, 14] or algebraic ones in [16]). Time delay is frequently introduced to break the algebraic loop [57], which appears when using the estimate $y^{(k)}(t) - u(t)$ in the control $u(t)$ itself.

Another difference between [14, 16, 17, 23, 27] consists in the type of feedback used for the system stabilization. Theoretically sliding-mode controls provide a finite-time exact cancellation of matched disturbances [27, 14], which is better than ε-invariance provided by linear feedbacks from [16, 17, 23, 57]. But in practice the sliding-mode controls suffer from chattering that returns them back to ε-invariance setting. A related difference is robustness with respect to different nonlinearities of $y, y^{(1)}, \dots, y^{(n)}$ hidden in F (for example, linear feedback treats only Lipschitz or linear perturbations). In order to improve robustness and to avoid chattering, an intermediate solution should be proposed between linear and sliding modes.

Homogeneous high-gain controls [6] and observers [36] are nice candidates for such an improvement. Due to homogeneity, local asymptotic stability of this systems implies global one, and robustness with respect to disturbances is inherited next [5]. Adjusting nonlinear gains in control and estimation algorithms from [6, 36] it is possible to get a needed degree of robustness with respect to F.

High order sliding modes have been proved to be effective in chattering attenuation while at the same time preserving the sliding mode properties, see [41]. Basically, the methodology consists of two steps:

- The design of a suitable output or sliding surface, y, in the state space such that the system exhibits the desired behavior.
- The appropriate sliding mode enforcement such that the output/sliding-surface is reached in finite time.

High Order Sliding Modes is actually a movement on a discontinuity set of a dynamic system understood in Filippov's sense, [15]. The simplest problem of such kind is to make the output y of a Single Input Single Output, SISO, system converge to zero in *finite-time*. Hence, the rth order sliding mode is determined by the equalities:

$$y = \dot{y} = \ddot{y} = ... = y^{r-1} = 0, \tag{1}$$

where r represents the relative degree. The total time derivatives $\dot{y}$, $\ddot{y}$, ..., $y^{(r-1)}$ are continuous functions of the state and the set (1) is a nonempty integral set, i.e. consists of Filippov trajectories. Finite time convergence of the subspace $(y, \dot{y}, \ddot{y}, ..., y^{r-1})$ can be achieved with the appropriate selection of a control algorithm. A summary of some ϵ-invariant control algorithms for the cases $r = 1, 2$ and n is presented in the table 1.

	Algorithm	Order
Conventional SM	$u = -\kappa_1 \text{sign}(y)$	1
Twisting	$u = -\kappa_1 \text{sign}(y) - \kappa_2 \text{sign}(\dot{y})$	2
ASOSM	$u = -\kappa_1 y - \kappa_2 \int_0^t \text{sign}(y) d\tau$	2
Super-Twisting	$u = -\kappa_1 \|y\|^{\frac{1}{2}} \text{sign}(y) - \kappa_2 \int_0^t \text{sign}(y) d\tau$	2
Continuous-SOSM	$u = -\kappa_1 \|y\|^{\alpha_1} \text{sign}(y) - \kappa_2 \|\dot{y}\|^{\alpha_2} \text{sign}(\dot{y}) - \kappa_3 \int_0^t \text{sign}(y) d\tau$	2
Homogeneous	$u = -\kappa_1 \|y\|^{\alpha_1} \text{sign}(y) - ... - \kappa_{r-1} \|y^{(r-1)}\|^{\alpha_{r-1}} \text{sign}(y^{(r-1)}) - \hat{F}$	n

Table 1: Control algorithms.

One of the most important features of the sliding mode approach is a *finite-time* reaching phase. However the corresponding Lyapunov functions may be non-smooth in this case. For twisting and super-twisting algorithms, the design of strong Lyapunov functions was introduced in [39] and [34]. The general case, including the homogeneous control law, remains still open as well as the Multi-Input Multi Output case.

6 Preliminary results.

Preliminary results cover three main fields: under-actuated systems, mobile hydraulics and resilient control design. Under actuated systems are more sensitive to parametric variations, uncertainties and external disturbances. One example is a parametrically excited crane, where the wave induced motions may contain significant energy resulting in payload oscillations of large amplitude. For shipboard cranes, this can bring the load into dangerous conditions for the ship, the cargo and the crew. Since much time and money can be wasted waiting for acceptable sea conditions, the development of new schemes, capable of transferring cargo in marginal conditions and solving the problems of regulation and tracking were presented in [8], [52], [53], [50], [51], [35] and [54]. The developed control algorithms are supported by strict Lyapunov methods, taking advantage of the main properties of periodic, under-actuated and nonlinear systems.

The modeling and control design for hydraulic manipulators have been a recent and important topic of my research. Hydraulic systems are the main component of several industrial activities such as forestry, agriculture and mining, where high torques, speeds and a large ratio between the delivered force and the size of the actuator are required. Focusing on mobile hydraulics where the system dynamics are characterized by strong nonlinearities, uncertainty in the parameters as well as the presence of un-actuated links, my research goal is the creation of innovative solutions for estimation and control. As an independent researcher and team leader, I lead two current projects: automation of industrial forestry cranes and automation of tractor front loaders in collaboration with the control systems development team at Ålö AB. Preliminary results were presented in [49], [46], [48], [1], [2] and [47].

7 Time Plan

The project will continue for two years covering three main activities: Design of new resilient control algorithms for multi-input multi-output nonlinear systems, design of robust methods for observation and differentiation under noise and uncertainty in measurements as well as in communications channels and new advanced motion control design applications for underactuated robotics and mobile hydraulics. A preliminary time plan is as follows:

1. In the first par of the project new resilient control algorithms for multi-input multi output nonlinear systems will be proposed and the methodology will be supported by strict Lyapunov analysis. This part will continue for around 10 months.

2. In the second part, more efficients methods for observation/differentiation under noise and uncertainty in measurements as well as in communications channels will be proposed. We are going to include the analysis of noise measurement providing the optimal design. This part will continue for around 10 months.

3. In the third and last part of the project the methods proposed in the first and second part will be implemented and tested on actual industrial applications. This part will continue for around 4 months.

8 Possible further generalizations of the problem

One extension is to design the corresponding desired outputs with the singular LQ methodology, where a possible way to choose an output or sliding set is the usage of a Linear-Quadratic performance index. An optimal output or sliding surface is designed as a solution of a singular optimal LQ problem with symmetric positive definite weighting matrix Q and free cost control ([44],[11],[32],[40],[3]) and it is well known from the theory of singular optimal control ([20],[42],[18]) that for the case when the weighting matrix is semi-positive definite, the dimension of the optimal stabilization set is less than $(n-1)$. Then, the order (relative degree) of the sliding surface and the order of the controller can be chosen based on the properties of a weighing matrix [7], [8]. Then it is reasonable to test all different cases of the order of singularity of the corresponding performance index in order to select the best suited case that brings the best performance results for a specified system.

9 Budget

Assigned to this project will be the applicant Carlos Vázquez, who will work full time on the project as a Junior Researcher for two years.

10 National and International Collaboration.

An important column in this project is collaboration, looking for synergies as well as new challenges where international and industrial teams converge in common objectives, we started an international collaboration between Umeå University and Inria Lille-Nord Europe, enhancing their potential and defining new research projects on robotics and advanced motion control. Particularly, new resilient methods of estimation and control were developed and preliminary results have been submitted to the 54th IEEE Conference on Decision and Control to be held in Osaka Japan during December 2015. On the other hand, a joint work with the control systems development team at Ålö AB has been the perfect opportunity to contribute with our expertise in advanced motion control and model based development for the creation of original automation solutions for tractor front loaders and preliminary result have been submitted to the 20th IEEE International Conference on Emerging Technologies and Factory Automation to be held in Luxembourg during September 2015. At the present time, my network include researchers from Russia, France, Mexico and Sweden.

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[57] K. Youcef-Toumi and S.-T. Wu. Input/output linearization using time delay control. *ASME Journal of Dynamic Systems Measurement and Control*, 114:10–19, 1992.

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	Carlos Vazquez	100

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	Total
1	Applicant	Carlos Vazquez	75	587,815	605,450	1,193,265
	Total			587,815	605,450	1,193,265

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	Total
1	Lokalkostnader	46,747	47,981	94,728
	Total	46,747	47,981	94,728

Running Costs

	Running Cost	Description	2016	2017	Total
1	Driftkostnader	Conferences and open accsess	80,000	80,000	160,000
	Total		80,000	80,000	160,000

Depreciation costs

Depreciation cost	Description	2016	2017

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	Total, applied	Other costs	Total cost
Salaries including social fees	587,815	605,450	1,193,265		1,193,265
Running costs	80,000	80,000	160,000		160,000
Depreciation costs			0		0
Premises	46,747	47,981	94,728		94,728
Subtotal	714,562	733,431	1,447,993	0	1,447,993
Indirect costs	230,329	236,412	466,741		466,741
Total project cost	944,891	969,843	1,914,734	0	1,914,734

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

1. Salary: Assigned to the this project will be the applicant Carlos Vazquez, who will work full time on the project as a Junior Researcher for two years.
2. Runing costs: Attending of conferences and open access publications.
3. Premises: Local costs including facilities, premises and cleaning.
4. Indirect costs: Infrastructure, resources and materials provided by the university.

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

CV and publications

CV

Ph. D. Carlos Vázquez

Education

Ph.D. in Automatic Control
HEI: Research Center of Advanced Studies, Cinvestav, Mexico City
Year: 2010
Thesis: Control of a ship board crane
Supervisor: Professor Joaquin Collado
Jury: Prof. Alexander Poznyak, Prof. Hebert Sira-Ramirez, Prof. Leonid Fridman.
Description: A parametrically excited crane affected by external perturbations was the main topic of my research, where the wave-induced motions may contain significant energy resulting in payload oscillations of large amplitude. For shipboard cranes, this can bring the load into dangerous condition for the ship, the cargo and the crew. Since much time and money can be wasted waiting for acceptable sea conditions, the development of new schemes, capable of transferring cargo in marginal conditions and solving the problems of regulation and tracking were proposed in the project. The methods are supported by strict Lyapunov methods and taking advantage of main properties of periodic, under-actuated and nonlinear systems.

M.Sc. in Automatic Control
HEI: Research Center of Advanced Studies, Cinvestav, Mexico City
Year: 2004
Thesis: Control of a 4 degrees of freedom convey crane.
Supervisor: Professor Joaquin Collado
Jury: Prof. Vladimir Kharitonov, Prof. Hebert Sira-Ramirez
Description: The maneuvering with convey crane systems has become the main part in many industrial activities where the efficiency in the cargo transportation process is crucial. This has motivated an intensive research, on modeling and control design, during last decades. Existing methods just handle the unperturbed case or in addition, the analysis is limited to 3 or 2 degrees of freedom. A wide range of processes cannot be restricted to these scenarios. Taking a step forward, the modeling, control and observer design for a 4 Degrees of Freedom Convey Crane system was developed during the project.

B.Sc. in Electronic Engineering, ITC; Celaya — 1998-2003

The integration of embedded systems as well as programmable logic controllers was the main specialization during my bachelor, with an emphasis in micro controllers and programming. An internship at GKN Driveline Mexico (formerly Velcon) gave me valuable experience in plc's programing. All this encouraged me to develop an automation solution for the climate control system of a greenhouse, in collaboration with the National Institute of Agriculture and Forestry Research in Mexico - INIFAP.

Experience

Junior Researcher, Umeå University; Umeå Sweden — 2013-Present

The modeling and control design for hydraulic manipulators is one of the main tasks. Focusing on mobile hydraulics and creating innovative solutions for estimation and control. As an independent researcher and team leader, participate in two current projects: 1. Automation of industrial forestry cranes and 2. Automation of tractor front loaders in collaboration with the control systems development team at Ålö AB and both projects are sponsored by Kempe foundation. Most of the research can be found on conferences and journal proceedings and it leverages scientific principles and advanced mathematics.

Postdoctoral Fellow, Unam; Mexico City — 2011-2012

The design of advanced motion control for under actuated mechanical systems with an emphasis on resilient and nonlinear techniques was one of the main goals. Particularly, complex tasks related with the transportation of suspended payloads under the presence of external perturbations, uncertainties and parametric variations were successfully solved for an Inteco test bench with a complete integration of Matlab/Simulink and real-time processing.

Assistant Professor, National Polytechnic Institute; Mexico City — 2009-2012

Member of the control division at the electronics and communications department. Mentor of three undergraduate courses: PLC's, servo- mechanisms and nonlinear systems; leader of two seminars: robotics and research methods, where in collaboration with other colleagues, conducted interdisciplinary thesis projects. The seminars were designed for students on their last year of engineering and are not limited to one specific career or faculty. Working in teams, the students were oriented and motivated to solve problems applying their technical and theoretical background.

Visitor Position

Inria, Lille France, November-December 2014.

Started an international collaboration between Umeå university and Inria, enhancing their potential and defining new research projects on robotics and advanced motion control. Particularly, new resilient methods of estimation and control were developed during my visit. Preliminary results have been successfully tested over our industrial platforms.

Invited talk. Control of a perturbed convey-crane: parametric resonance case study. School of Electrical Engineering, Royal Institute of Technology, Stockholm, Sweden, January 22nd, 2015.

Publication list

List of Publications

Journal papers

- Vázquez C., S. Aranovskiy , L. Freidovich and L. Fridman. Time-Varying Gain Differentiator: A Mobile-Hydraulic System Case Study. Submitted for journal publication (under second revision), 2015.
- Vázquez C., L. Fridman, J. Collado and I. Castillo. Control of a perturbed crane. Journal of Dynamic Systems, Measurement and Control. Accepted for publication, 2015. **Impact factor: 1.175**.
- Vázquez C., J. Collado and L. Fridman. Super-Twisting Control of a Parametrically Excited Crane. Journal of the Franklin Institute. Vol. 351, Issue 4, pp. 2283-2298, 2014. **Impact factor: 2.26**.
- Vázquez C., J. Collado and L. Fridman. Control of a Parametrically Excited Crane: a Vector Lyapunov Approach. IEEE Transactions on Control Systems Technology, Vol. 21, Issue 6, pages: 2332-2340. November 2013. **Impact factor: 2.521**.
- Moreno-Ahedo L., J. Collado and C. Vázquez. Parametric resonance cancellation via reshaping stability regions: numerical and experimental results. IEEE Transactions on Control System Technology, Vol. 22, Issue 2, pages: 753-760, March 2014. **Impact factor: 2.521**.
- Vázquez C. and J. Collado. Optimal Delayed Control for an Overhead Crane. Annals of the University of Craiova, Series: Automation, computers, electronics and mechatronics. ISSN: 1841-0626. Volume 6(33) issue 2 pp. 94-99, 2009.

Book chapter

- Vázquez C., J. Collado and L. Fridman. Variable Structure Control of a Perturbed Crane: Parametric Resonance Case Study. In Recent Advances in Sliding Modes: From Control to Intelligent Mechatronics. X. Yu, O. Efe (eds), Studies in Systems, Decision and Control, Springer, 2015.

Conference contributions

- Castillo I., C. Vázquez and L. Fridman. Overhead Crane Control through LQ Singular Surface Design MATLAB Toolbox. American Control Conference, Chicago, IL, USA, 2015.
- Vázquez C., S. Aranovskiy and L. Freidovich. Second Order Sliding Mode Control of a Mobile Hydraulic Crane. 53rd IEEE Conference on Decision and Control, Los Angeles California, 2014. pp. 5530-5535.
- Aranovskiy S. and Vázquez C. Control of a Single-Link Mobile Hydraulic Actuator with a Pressure Compensator. IEEE Multi-conference on Systems and Control, Antibes, France 2014. pp. 216-221.

- Vázquez C., S. Aranovskiy and L. Freidovich. Time-Varying Gain Second Order Sliding Mode Differentiator. 19th IFAC World Congress, Cape Town, South Africa, August 2014. pp. 1374-1379.
- Vázquez C., S. Aranovskiy and L. Freidovich. Sliding Mode Control of a Forestry-Standard Mobile Hydraulic System. 13th International Workshop on Variable Structure Systems, Nantes, France 2014.
- Aranovskiy S., A. Losenkov and C. Vázquez. Position Control of an Industrial Hydraulic System with a Pressure Compensation. 22nd Mediterranean Conference on Control and Automation, Palermo 2014. pp.1329-1334.
- Vázquez C., L. Fridman and J. Collado. Second Order Sliding Mode Control of an Overhead-Crane in the Presence of External Perturbations. IEEE Conference on Decision and Control. Florence, Italy, 2013. pp. 2876-2880.
- Vázquez C., L. Fridman and J. Collado. On the Second Order Sliding Mode Control of a 3-Dimensional Overhead Crane. IEEE Conference on Decision and Control, Maui Hawaii 2012.
- Vázquez C., L. Fridman and J. Collado. On the Second Order Sliding Mode Control of a Parametrically Excited Crane. American Control Conferenc, Montreal 2012. . pp. 6288-6293.
- Vázquez C., L. Fridman and J. Collado. Generalized Twisting Controller of a Parametrically Excited Crane. The 12th International Workshop of Variable Structure Systems. pp. 111-116, Bombay India 2012.
- Vázquez C. and J. Collado. Control of a parametrically excited crane. The 18th IFAC World Congress, Milan, Italy 2011. pp. 6703-6708.
- Moreno-Ahedo L. and C. Vázquez. Periodic stabilizing matrices: A monodromy matrix approach. 21st International Conference on Electrical Communications and Computers, pp. 46-49, Mexico 2011.
- Vázquez C. and J. Collado. Oscillation attenuation in an overhead crane: comparison of some approaches. The 6th International Conference on Electrical Engineering, Computing Science and Automatic Control. Mexico, 2009.
- Villafuerte R., S. Mondie, C. Vázquez and J. Collado. Proportional retarded control of a second order system. The 6th International Conference on Electrical Engineering, Computing Science and Automatic Control. Mexico, 2009.

CV

Name: Carlos Vazquez	**Doctorial degree:** 2010-09-29
Birthdate: 19800219	**Academic title:** Doktor
Gender: Male	**Employer:** Umeå universitet

Research education

Dissertation title (swe)
Styrning av ett shipboard kran

Dissertation title (en)
Control of a shipboard crane

Organisation	Unit	Supervisor
Research Center of Advanced Studies, Mexico Not Sweden - Higher Education institutes	Automatic Control Department	Joaquin Collado

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
20202. Reglerteknik		2010-09-29

Publications

Name: Carlos Vazquez	**Doctorial degree:** 2010-09-29
Birthdate: 19800219	**Academic title:** Doktor
Gender: Male	**Employer:** Umeå universitet

Vazquez, Carlos 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.