University Academic Curriculum Vitae

Personal information

Name: Marco Frego
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Education since leaving school

- 2008, Laurea Triennale in matematica, Univ. Di Trento
- 2010 Laurea Specialistica in matematica, Univ. Di Trento
- 2014 PhD in Mechatronics, Ing. dei sistemi strutturali, civili e meccanici, Univ. Di Trento

Present appointment

- Post-doc A/R at the University of Trento
  50% dep. Industrial Engineering (DII) – 50% dep. Information Engineering and Computer Science (DISI)
- I am in this group since September 2015.

I was the senior post-doc of the research group led by prof. Biral (DII) and prof. Palopoli (DISI). I led the research activities on the EIT-Digital project AWARD and H2020 Safestrip, that included the development of an autonomous forklift prototype. I managed the work of the other PhD students and junior post-docs (a total of 5 people), my contribution included the interface with the other industrial partners (Brightcape and UPS) and the develpment of a traffic management system to coordinate a fleet of AGVs. I was contract professor during AY 2018/2019 for the course of *Fondamenti di Informatica e Calcolo Numerico* (for the BS in Ind. Eng.)
I was also teaching assistant to prof. Bertolazzi (of our research group) in the courses of *Fondamenti di Informatica e Calcolo Numerico* (for AY 2019-2020) and *Computational Methods for Mechatronics* (for the MS in Mechatronics).

Professional experience

From / to	Job title	Name of academic Institution	Academic level	responsibilities
2019/2020	H2020 Safestrip	UniTN	Researcher A/R	Scientific responsibility of traffic coordination for autonomous vehicles at intersections.
2018/2019	Eit-Digital Award	UniTN	Researcher A/R	Scientific responsibility optimization of AGV in an automated warehouse
2017/2018	H2020 Acanto	UniTN	Researcher A/R	Developer of path planning methods for assistive robots
2015/2017	OptHySys	UniTN	Researcher A/R	Coordinator and Scientific responsibility for optimal control system for autonomous vehicles
2014/2015	Wiss. Mitarbeiter	Hamburg Univ. of Technology TUHH	Wiss. Mitarbeiter	Assistant prof. for the course of general mathematics
Summer 2010	H2020 Veritas	UniTN	Researcher A/R	Scientific responsibility for a garment for sterevision
2009/2010	Internship	Integrated Device Technology IDT - Milan	Internship	Scientific responsibility for studying properties of codes inside solid state disk SSD.

Since the PhD, most of my research was conducted in the context of

European Projects. During the PhD (project Veritas), I developed a control system for the faulty detection of markers on a garment for the 3D reconstruction of the human body for rehabilitative purposes. This system has been also patented (see the CV for more details). In the last years I had an active participation in the H2020 project ACANTO (ref. PI prof. Palopoli) for the development of the path and activity planner of a walker for elder people. Within SAFEStrip I developed a smoothing technique for the data acquired by high performance racing cars. Within the EIT-Digital project AWARD I designed an optimal traffic management system for coordinating a fleet of autonomous forklifts in an automated warehouse. More of these results can be found in the published literature, see my publication list.

Other partners involved in the scientific transfer are the Laboratory of Industrial Mathematics and Cryptography of the University of Trento, ref. prof. Sala.
I got in touch with industrial partners as Integrated Device Technology - IDT. Within the context of the projects I collaborated with the General Hospital of Trento (Italy) and Getafe (Spain), with Dutch logistic industries such as Brightcape and UPS (ref. prof. Palopoli) and with some famous Italian automotive houses (NDA, ref. prof. Biral).

Recently, I have been collaborating with Matlab/MathWorks about the Clothoid Toolbox and the associated book (ref. prof. Bertolazzi). I am also in touch with the German Aerospace Center (Deutsches Zentrum fur Luft- und Raumfahrt - DLR, ref. dr. P. Petit) that is interested in clothoids for designing the trajectories of modern helicopters.

Participation in exhibitions (where applicable)

For the participation at conferences, see “Further data” below.

Experience in academic teaching

- Contract professor for “Fondamenti di Informatica e Calcolo Numerico” for the BS in Industrial Engineering at UniTN, AA 2017/2018 and AA 2018/2019. The students’ final evaluation was in the median of the department.
- Instructor for “Computational Methods for Mechatronics” for the MS in Mechatronics at UniTN for the years 2010-2020 without 2015 and 2016.
- In the course of “Computational Methods for Mechatronics” I was instructor for almost ten years, I was appreciated by the students (last year I got 100%). I teach my lectures writing on the tablet instead of the blackboard, so students can get my hand-written notes after the lectures, they seem to like this a lot. I share them on cloud Google Classroom, together with the slides and the Latex course notes (an exercise book).
- Instructor for “Matematica e Statistica I” for the BS in Biotechnologies at UniTN
- I supervised (unofficially) dr. Paolo Bevilacqua along his 3-y phd in computer science and robotics, he is a strict co-author and colleague in many EU projects.

Other academic responibilities

- I participated to some degree commissions for the BS in Industrial Engineering in AA 2017/18 and 2018/19.
- I have been coordinator for the project OptHySys of the Province of Trento.
- I was selected as chair three times at the European Control Conference in 2016 and 2018.

I served as reviewer for the following journals/conferences:
IEEE-TAC, JCAM, Mathematical Reviews, IEEE-RAL, IROS, ECC and Intelligent Vehicles.

My h-index is 9 and I have about 200 citations. I have submitted to the ASN – Abilitazione Scientifica Nazionale (Italian National Academic Qualification) as Associate Professor in 01/A5 Numerical Analysis and I plan to submit soon also for 01/B1 Computer Science and for 09/G1 Automatica.

Memberships

n/a

Research and scholarships

My research field is in robotics, a topic that covers different aspects of science and technology. I publish mainly in three subjects:

• Applied Mathematics, where I developed the tools for the handling of clothoid curves, a motion primitive for path planning. I studied the numerical algorithms for the most used functionalities, that can be considered as state-of-art.

• Automation and Control Engineering, where I applied most of my mathematical algorithm to autonomous vehicles: racing cars and assistive walkers. A recent contribution is the design of an optimal controller for the speed profile of a car-like vehicle subject to dynamic constraints and a reactive planner that drives the walker in case of unforeseen events. I have also proposed a new formalisation and solution of the Markov-Dubins problem.

• Computer Science, where I implemented in a Matlab Toolbox and C++ library the algorithms for path planning with clothoids and other curves. I also recently published an activity planner that designs an optimal visit to a museum taking into account probabilistic constraints as a Chance Constrained Stochastic Programming.
Other minor research directions are in the field of numerical linear algebra, CAD-CAM, coding and cryptography.

I published my papers in the top journals of the above mentioned fields, such as the SIAM Journal on Scientific Computing (SISC, IF 1.976 Q1 87%), Automatica (IF 5.541 Q1 97%), IEEE Transactions of Industrial Informatics (TII, IF 9.112 Q1 98%), IEEE Robotics and Automation Letters (RA-L, IF 3.608 Q1 95%) and others. In several of them I am first author, I am the only author of a paper. I participated at the principal top conferences on robotics and applied mathematics, such as ICRA, IROS, CDC, ECC, IMACC, MASCOT and others, where I had the honour of being session chair for trajectory optimisation, computational methods, agents and autonomous robots.
I have not directly obtained grants in project, I only helped in writing several proposals.

Publications:
2020 **(*)**

Minimum Time—Minimum Jerk Optimal Traffic Management for AGVs
M Frego, P Bevilacqua, S Divan, F Zenatti, L Palopoli, F Biral, D Fontanelli, IEEE Robotics and Automation Letters 5 (4), 5307-5314
DOI: 10.1109/LRA.2020.3007435

An Iterative Dynamic Programming Approach to the Multipoint Markov-Dubins Problem
M Frego, P Bevilacqua, E Saccon, L Palopoli, D Fontanelli
IEEE Robotics and Automation Letters 5 (2), 2483-2490
DOI: 10.1109/LRA.2020.2972787

Activity Planning for Assistive Robots using Chance Constrained Stochastic Programming
(*) P Bevilacqua, M Frego, L Palopoli, D Fontanelli
IEEE Transactions on Industrial Informatics
DOI: 10.1109/TII.2020.3012094

Efficient intersection between splines of clothoids
E Bertolazzi, P Bevilacqua, M Frego
Mathematics and Computers in Simulation 176, 57-72
DOI: 10.1016/j.matcom.2019.10.001

Point data reconstruction and smoothing using cubic splines and clusterization
(*) E Bertolazzi, M Frego, F Biral
Mathematics and Computers in Simulation
10.1016/j.matcom.2020.04.002

A novel formalisation of the Markov-Dubins Problem
P Bevilacqua, *M Frego,* D Fontanelli, L Palopoli,
Proceedings of the European Control Conference 2020, pp. 1987-1992,12-15 May 2020, Saint Petersburg, Russia.
DOI: n/a, https://ieeexplore.ieee.org/document/9143597

2019

Point-Clothoid Distance and Projection Computation
(*) M Frego, E Bertolazzi
SIAM Journal on Scientific Computing 41 (5), A3326-A3353
DOI: 10.1137/18M1200439

Interpolating Splines of Biarcs from a Sequence of Planar Points
E Bertolazzi, M Frego, F Biral
Computer-Aided Design & Applications 18 (1), 66-85
DOI: 10.14733/cadaps.2021.66-85

A Note on Robust Biarc Computation
E Bertolazzi, M Frego
Computer-Aided Design & Applications 16 (5), 822-835
DOI: 0.14733/cadaps.2019.822-835

2018

On the G2 Hermite interpolation problem with clothoids
E Bertolazzi, M Frego
Journal of Computational and Applied Mathematics 341, 99-116
DOI: 10.1016/j.cam.2018.03.029

Efficient re-planning for robotic cars
E Bertolazzi, P Bevilacqua, F Biral, D Fontanelli, M Frego, L Palopoli
2018 European Control Conference (ECC), 1068-1073
DOI: 10.23919/ECC.2018.8550215

On the distance between a point and a clothoid curve
M Frego, E Bertolazzi
2018 European Control Conference (ECC), 1-6
DOI: 10.23919/ECC.2018.8550554

Interpolating clothoid splines with curvature continuity
E Bertolazzi, M Frego
Mathematical Methods in the Applied Sciences 41 (4), 1723-1737
DOI: 10.1002/mma.4700

Reactive planning for assistive robots
P Bevilacqua, M Frego, D Fontanelli, L Palopoli

	IEEE Robotics and Automation Letters 3 (2), 1276-1283 DOI: 10.1109/LRA.2018.2795642
(*)	Clothoids: A C++ library with Matlab interface for the handling of Clothoid curves E Bertolazzi, P Bevilacqua, M Frego Rend. Sem. Mat. Univ. Pol. Torino 76 (2), 47-56
2017	On the probability of incorrect decoding for linear codes M Frego IMA International Conference on Cryptography and Coding, 103-115 Lecture Notes on Computer Science 10655 DOI: 10.1007/978-3-319-71045-7_5
(*)	Semi-analytical minimum time solutions with velocity constraints for trajectory following of vehicles M Frego, E Bertolazzi, F Biral, D Fontanelli, L Palopoli Automatica 86, 18-28 DOI: 10.1016/j.automatica.2017.08.020
	Semianalytical minimum-time solution for the optimal control of a vehicle subject to limited acceleration E Bertolazzi, M Frego Optimal Control Applications and Methods DOI: 10.1002/oca.2376
2016	Trajectory planning for car-like vehicles: A modular approach M Frego, P Bevilacqua, E Bertolazzi, F Biral, D Fontanelli, L Palopoli 2016 IEEE 55th Conference on Decision and Control (CDC), 203-209 DOI: 10.1109/CDC.2016.7798270
	Path planning maximising human comfort for assistive robots P Bevilacqua, M Frego, E Bertolazzi, D Fontanelli, L Palopoli, F Biral 2016 IEEE Conference on Control Applications (CCA), 1421-1427 DOI: 10.1109/CCA.2016.7588006
	Semi-analytical minimum time solutions for a vehicle following clothoid-based trajectory subject to velocity constraints M Frego, E Bertolazzi, F Biral, D Fontanelli, L Palopoli 2016 European Control Conference (ECC), 2221-2227 DOI: 10.1109/ECC.2016.7810621
2015	Preconditioning complex symmetric linear systems E Bertolazzi, M Frego Mathematical Problems in Engineering 2015 DOI: 10.1155/2015/548609
(*)	G1 fitting with clothoids E Bertolazzi, M Frego Mathematical Methods in the Applied Sciences 38 (5), 881-897 DOI: 10.1002/mma.3114
2014	A non-linear constrained optimization technique for the mimetic finite difference method G Manzini, D Svyatskiy, E Bertolazzi, M Frego Los Alamos National Lab.(LANL), Los Alamos, NM (United States) LA-UR-14-27620
Publications <u>about</u> the applicant	n/a
Further data	I presented as speaker at the following conferences in the last 3 years

2017 - Cryptography and Coding: 16th IMA International Conference, IMACC 2017, Oxford, UK with the paper
On the probability of incorrect decoding for linear codes

2018 – IEEE/IFAC European Control Conference, Limassol, Cyprus, with two papers
Efficient re-planning for robotic cars
On the distance between a point and a clothoid curve

2018 - MASCOT2018-15th MEETING ON APPLIED SCIENTIFIC COMPUTING AND TOOLS, Rome, Italy with the paper
Efficient intersection between splines of clothoids

2020 - IEEE International Conference on Robotics and Automation - *ICRA 2020*, Paris, France, An Iterative Dynamic Programming Approach to the Multipoint Markov-Dubins Problem

2020 – IEEE/IFAC European Control Conference, St. Petersburg, Russia, with the paper A novel formalisation of the Markov-Dubins Problem

2020 - IEEE/RSJ International Conference on Intelligent Robots and Systems IROS2020 with the paper Minimum Time—Minimum Jerk Optimal Traffic Management for AGVs

Entrepreneurship

I share with A. Fornaser and E. Bertolazzi the patent “Dispositivo e metodo per la ricostruzione discreta di forma e posizione tridimensionale”. N.0001423079 Ministero dello Sviluppo Economico, Ufficio Italiano Brevetti e Marchi.
A device for the discrete 3D reconstruction of shapes and positions.

I was a co-founder of the start-up “MathNow” of the dep. Of Mathematics at UniTN with prof. Sala and prof. Bertolazzi. This brough to the foundation of the Laboratory of Industrial Mathematics and Cryptography of UniTN. MathNow is now part of De componendis cifris (ref. prof. M. Sala).

Statement of interest

I can offer to UniBZ a strong applied mathematical background and foundation to the research activities, I have some experience (with engineers and computer scientists) to interact with non purely mathematical-oriented scientists.
Based on the above experience and on courses I attended during the PhD and the post-doctoral courses, I feel confident in offering my expertise on one or more of the following subjects:

- “Optimization”, a background of differential calculus, concepts of convexity, static optimization (NLP and SQP), background of functional analysis, calculus of variations, optimal control with the indirect method, outlines of the direct method and of dynamic programming, singular optimal control problems, use of the principal open source software for OCP. These arguments were the subjects of my PhD thesis.

- “Numerical Analysis”, the subjects of a classic course: real linear systems, eigenvalues, ODE, integration, splines, curve and Bezier fitting. I have several published articles on clothoids curves, recently cited as the state of the art. Another published paper is about a polynomial preconditioner for linear systems. Another important field is the one of hierarchical algorithms and matrix computations, studied recently at the TUHH. A combination of these themes could be the topic for a

course of mathematics for robotics.

- “Computational Methods for Mechatronics”, the principal integral transform: Fourier (all the family), Laplace, Z, an outline of the theory of the related functional spaces with the complex inversion formula and several examples of applications, to signal processing, to PDE with Finite Elements, electrical circuits. I followed as assistant professor this course at UniTN (ref. prof. Bertolazzi).

- “Coding Theory and Cryptography”, the algebraic foundations of coding, finite fields, groups and rings of polynomials, the classic theory of ECC, Hamming codes, cyclic codes, BCH codes, Reed-Solomon and Reed-Muller, bounds on the dimension and distance, weight distribution, error probabilities, the effective decoding scheme with the error locator polynomial and Grobner bases, computational algebra with CAS like Magma or Singular. ¨On cryptography: key scheduling of the AES and of Serpent, a complete description of AES, the communication channel, an outline of public key schemes like RSA and cryptography on elliptic curves with the equivalent of the discrete logarithm.

Language competence

C1 English certificate from the Hamburg University of Technology.
C1 German certificate from the Hamburg University of Technology.

Date
11/09/2020

Signature
Marco Frego