Johannes Wallner

Institute of Geometry
TU Graz
Kopernikusgasse 24
A 8010 Graz

Website: *http://www.geometrie.tugraz.at/wallner*

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Academic Curriculum vitae

I was born on May 14, 1971 in Scheibbs (Lower Austria), and for the next 18 years lived in the small market of Gresten (Lower Austria). After graduation from the *Gymnasium* in Wieselburg on June 15, 1989, I moved to Vienna in order to study Mathematics and Geometry on the one hand, and Mechanical Engineering on the other. I finished these programs in June 30, 1994 and December 13, 1995, respectively, and received the degrees of Mag.rer.nat. and Dipl.Ing.

Even as a student I had been employed half time at the Institute of Geometry at TU Wien (from September 17, 1990 to august 31, 1994); after graduation I worked full time, besides pursuing my Ph.D. under the supervision of Helmut Pottmann. I finally received the degree of Dr.techn. on November 12, 1996.

My military service had been postponed because of university studies, and I chose to do a year of alternative service with Vienna's communal hospitals (October 1997 to September 1998). I applied for and was awarded *Habilitation* for the area 'geometry' on March 23, 2000, which under the then regulations implied a permanent position at TU Wien.

In the winter term 2000/2001 (October 1 to March 31) I served as a temporary C3 professor at TU Darmstadt. Since January 1, 2007 I am a professor at the Institute of Geometry at TU Graz. I am currently living in Graz in the south of Austria, where my duties besides research and the establishing of a working group of students is teaching on various geometric subjects to students of Mathematics, Computer Science, various engineering programs, and last, but not least, for a small group of students who are to become teachers of Mathematics and Geometry in Austrian high schools.

Research Interests

The greater part of my work can be summarized under geometry processing or geometric modeling, whereas my work on nonlinear subdivision processes in the last years belongs to approximation theory.

I enjoy working in these areas of research, because here the pure mathematics in most cases is inspired by applications and real world problems, without lacking a rich theory and deep results. The interaction between applications on the one hand and theory on the other has been a driving force in the development of mathematics at all times and still is present in a substantial part of the work done today.

In the following text I briefly summarize various areas I have been working in.

Geometric Spline Theory. The notion of 'geometric' spline means curves and surfaces useful for approximating with, and doing geometric modeling with, but with a focus on geometry rather than on numerical analysis or approximation theory. Not only does the geometric viewpoint yield an elegant approach to properties of splines relevant to numerics, but we also consider splines in manifolds and in general splines within nonlinear environments.

My interest in geometric splines began with the Ph.D. thesis [65, 3, 5]. By introducing *spline orbifolds*, my Ph.D. advisor H. Pottmann and myself solved the problem of finding spline spaces subordinate to a triangulation of a compact surface of arbitrary genus. I worked on geometric design of developable surfaces [9, 11], splines in various geometries [7, 6, 25], near-interpolating splines [23, 30], and splines as energy-minimizing curves in manifolds [59, 45].

Distance Geometry. While I am far from having worked extensively in that area, my interest dates back to the thesis [63]. Later I returned to this fascinating topic with [27], where we established the validity of Ivory's theorem in spaces of constant curvature. In [51] we sought for a deeper understanding of Voronoi diagrams in Minkowski spaces which have an interpretation as space-times in special relativity.

Geometry of NC milling. My work in this area started in the course of a funded project where I have been a co-investigator. I contributed to the geometry of NC milling, especially on global millability questions and the avoiding of collisions, which are connected to both shape and topology of an object to be manufactured [8, 10, 12, 18]. This topic is interesting from the mathematical viewpoint, as differential topology allows to derive global theorems from comparing infinitesimal properties of surfaces, similar to Blaschke's rolling ball theorem.

Kinematics and Configuration spaces. This topic is in part the previous one seen from a more abstract viewpoint. In this context I investigated the configuration space of surface-surface contact i.e., a subset of the Euclidean motion group consisting of the positions of one smooth body which touches another one [13, 14, 15].

My first work in kinematics is [2], which considers superposition of subgroups in Lie groups for the purpose of Taylor approximation.

Work on line geometry in connection with the reconstruction of point cloud surfaces from normal element data, which is also kinematic in nature [17, 22, 24, 26, 42, 35] is discussed in the line geometry section below. A few years ago I have worked in kinematics once more, namely in relation with geometric tolerance analysis [34].

Line Geometry and Reverse Engineering. The geometry of lines occurs naturally in many geometry processing applications, e.g. in the context of surface-like point clouds with normal vectors. In connection with kinematic properties of surfaces (like the property of possessing an automorphic Euclidean congruence transformation), line geometry is an essential tool in reverse engineering applications, and the classification, reconstruction, and inspection of surfaces.

Besides purely geometric work on line geometries in a more general sense [21, 42], the connections of line geometry with kinematics and shape classification problems are the topic of [17, 24, 22]. The paper [26] and recent work on line elements [35] aim towards the Computer Vision community. I coauthored the book [1], which treats line geometry in a broad sense with a focus on computing.

Geometric Tolerance Analysis. The geometric analysis of errors means the manipulation of subsets of d-dimensional Euclidean space (usually $d = 2, 3$) and other geometries. In the earlier papers [16, 19] we considered error propagation through linear geometric constructions, like spline curves defined by imprecisely defined control points. In the course of a project funded by the Austrian Science Fund (FWF), besides the papers [28, 32, 44, 49], we investigated error bounds for implicitly defined objects. This analysis depends on the fact that in many cases, implicit equations in geometry are quadratic [29, 37]. In [33] we considered the Euclidean motion group from a tolerancing viewpoint. Probabilistic errors in planar geometry are the topic of [38].

The paper [34] studies the behaviour of a rigid body which assumes an unorganized point-cloud like set of positions in space. We give an algorithm for computing the swept volume which reduces the dimensionality of the problem from a priori six down to two. This problem occurs e.g. when computing bounding volumes of a rigid body which undergoes an unstructured small motion, like the vibration of a mechanical part. In [40] we considered the problem of smoothing digital elevation data in the presence of hard constraints (i.e., tolerance zones).

Nonlinear subdivision processes. Subdivision algorithms play a prominent role in Computer Graphics, in Geometric Modeling, and in connection with wavelets. In recent years there is growing interest in subdivision processes which work in nonlinear geometries, like surfaces, Riemannian manifolds, Euclidean space minus obstacles, or Lie groups. I have been working actively towards a systematic theory of proximity and smoothness of nonlinear subdivision schemes [31, 41], and meanwhile a rich class of nonlinear analogues of linear univariate subdivision schemes has been investigated with regard to convergence, and smoothness [31, 41, 47, 56]. Applications relevant for the Computer Graphics community are treated in [36]. Work in this area is supported by the Austrian Science Fund (FWF) by two grants.

Computational Differential Geometry. The investigation of shape characteristics of digital data is one of the fundamental tasks in geometry processing. It includes recognition of features at various scales and the computation of curvatures in a robust way. Our contributions to this subject are contained in [54, 55], where we analyze the method of integral invariants for the computation of curvatures from the viewpoint of asymptotics and robustness against noise. Also the work on feature-sensitive geometry processing in [39] belongs in this section.

A different topic is *discrete differential geometry*, which is concerned with a discrete theory of curvatures, minimal surfaces, and other topics which are known in the smooth setting. Here we have mainly investigated the so-called conical meshes [46] and the discrete minimal surfaces among them. [48]. The motivation for this work comes from geometric problems which arise in the realization of freeform surfaces in architectural design (see the next section).

Polyhedral freeform surfaces with applications in architecture. The realization of freeform surfaces as a steel-glass construction is a nontrivial task – one first has to face the geometric problem of segmentation of that surface into planar parts, which requires geometric knowledge and optimization effort. A closely related geometric problem is the existence of meshes at constant distance from each other, and of determining a beam layout with low node complexity and feasible dimensions [50]. We contributed to this topic by introducing the new concepts of *conical meshes* [43, 53, 46] and a theory of parallel meshes which allows to deal with beam layout and optimized nodes [52]. It is very interesting that this work is intimately connected with discrete differential geometry and the solution of problems in this area draw on deep mathematical results even if they come directly from rather 'practical' questions.

Together with Waagner Biro Stahlbau we have been able to acquire a grant which supprts work on more practical and implementation-related issues, with the aim of creating an effective tool usable by architects, designers, and engineers. This project is starting this summer.

Funding Received

The funding institutions I have successfully obtained grants from are the Austrian Science Fund (Fonds zur Förderung der wissenschaftlichen Forschung, FWF) which is under the supervision of the Ministry of Education and Research; and the Österreichische Forschungsförderungsgesellschaft (FFG) which is connected to the Ministry of traffic, innovation and technology.

I have been a co-investigator of the following projects:

• *P11357 (FWF): Geometric Design of Developable Surfaces*, submitted by H. Pottmann as principal investigator TU Wien, 1997–1999, EUR 25.400,–

• *P13938 (FWF): Geometric Computing for 5-Axis Sculptured Surface Machining*, submitted by H. Pottmann as principal investigator, TU Wien, 2000-2002, EUR 73.200,–

• *S92 (FWF): Joint Research Network "Industrial Geometry"*, submitted by a consortium of principal investigators and co-investigators from 5 universities. Chairman is B. Jüttler. The grant money for TU Wien is EUR 384.000,– (2005–current).

As a principal investigator I have acquired the following grants:

• *P15911 (FWF) Geometric Set Operations and Tolerance Analysis for CAD.* TU Wien, 2002–2005, EUR 144.000,–.

• *P18575 (FWF): Smoothness of nonlinear subdivision algorithms.* TU Wien 2006 – TU Graz 2007. Total amount: EUR 92.500,–.

• *P19780 (FWF): Multivariate subdivision processes.* Total amount: EUR 143.200,–, at TU Graz. This project is scheduled to start in September 2007.

• *813391 (FFG): Multilayer Freeform Structures.* submitted by H. Pottmann, J. Wallner, S. Brell-Cokcan, and Waagner Biro Stahlbau. Total amount: EUR 541.220,–, from which EUR 112,200,– are spent at TU Graz. This project is scheduled to start in August 2007.

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