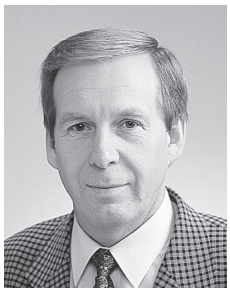
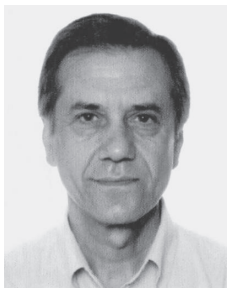
Computer Graphics Laboratory



Gennadiy Nikishkov
Professor

Pierre-Alain Fayolle
Associate Professor

Yohei Nishidate
Associate Professor



Matvienko Yury
Visiting Researcher

The Computer Graphics Lab conducts research into physics-based modeling of different phenomena, their visualization and animation. Innovative approaches to graphical user interfaces and direct interaction methods, modeling, rendering, simulation and scientific visualization are under development. Created mathematical models are used for graphical representation of natural processes.

Research areas include:

- Visualization of surface and volume data, which results from finite element, boundary element and finite difference modeling.

- Nanomechanics modeling. Finite element and molecular mechanics modeling of micro- and nanostructures.

- Augmented reality interface for different fields of human activity.

- Using graphics processing units for physics-based modeling and animation.

- Development of algorithms for shape modeling, analysis and understanding (operations on shape, segmentation and reconstruction).

- Investigation of algorithms for the polygonization of implicit surfaces (adaptative and robust polygonization, fast polygonization).

Professors of the Computer Graphics Laboratory deliver courses in Computer Graphics, Numerical Analysis, Modeling and Visualization. Graduation projects are related to computer graphics, human-computer interaction, physics-based modeling, visualization, and animation.

Refereed Journal Papers

[fayolle-01:2013] Pierre-Alain Fayolle and Alexander Pasko. Segmentation of discrete point clouds using an extensible set of templates. *The Visual Computer*, 29(5):449–465, 2013.

We present an algorithm for segmenting a discrete three-dimensional point-set (i.e., partitioning an input discrete point-set into appropriate subsets). The algorithm consists in the iteration of two main steps which are: fitting the parameters of template primitives from a user-specified list of primitives and extracting the points from the input point-set matching the best fitted primitive. We illustrate the results of applying our algorithm to several examples of three-dimensional point-sets.

[fayolle-02:2013] Alexander Belyaev, Pierre-Alain Fayolle, and Alexander Pasko. Signed Lp-distance fields. *Computer-Aided Design*, 45(2):523–528, 2013.

We introduce and study a family of generalized double-layer potentials which are used to build smooth and accurate approximants for the signed distance function. Given a surface, the value of an approximant at a given point is a power mean of distances from the point to the surface points parameterized by the angle they are viewed from the given point. We analyze mathematical properties of the potentials and corresponding approximants. In particular, approximation accuracy estimates are derived. Our theoretical results are supported by numerical experiments which reveal the high practical potential of our approach.

[nisidate-01:2013] Y. Nishidate. Closed-form analytical solutions for ray-tracing in optically anisotropic inhomogeneous media. *Journal of Optical Society of America A*, 30(7):1373–1379, 2013.

Closed-form analytical solutions are obtained for ray-tracing in several types of optically anisotropic inhomogeneous media whose optical properties are characterized by a matrix form of the inhomogeneous dielectric tensor in principal coordinates. The first solution is for an anisotropic axial media, and the second solution is for meridional rays in epsilon-negative metamaterial, and the third solution is an approximate one for rectangular lenses fabricated by molding procedures. The validation of numerical ray-tracing procedures for optically anisotropic inhomogeneous media was widely ignored since the solution was not available, and thus the present solutions are also useful for the validation. Furthermore, as examples of validation, ray trajectories are calculated by the closed-form

solutions and their results are compared with those obtained by a numerical solution of the geodesic equation which can be interpreted as a generalized ray equation.

Refereed Proceeding Papers

[nisidate-02:2013] G. P. Nikishkov and Y. Nishidate. Modeling of self-rolling nanostructures. In *The 2nd International Conference on Materials, Energy and Environment (ICMEE'13)*, pages ICMEE–121, Yokohama, Japan, 2013.

Self-rolling of nanohinges consisting of GaAs and InAs layers were investigated. Values of hinge curvature radius were determined depending for varying thickness and orientation of atomic planes. It was demonstrated that results obtained with continuum mechanics approach coincided with those of atomic-scale modeling for nanohinges of large thickness.

[nisidate-03:2013] G. P. Nikishkov and Y. Nishidate. Influence of scale and anisotropy on self-positioning of multi-layer nanostructures. In *Procs. of the 2013 World Congress on Advances in Nano, Biomechanics, Robotics, and Energy Research (ANBRE13)*, pages 834–839, Seoul, South Korea, 2013.

We present results of computational investigation of influence of nanostructure thickness and material anisotropy on self-positioning of bilayer strain-driven nanostructures. The atomic-scale nite element method (AFEM) based on molecular mechanics approach is used for calculating equilibrium atomic configurations after self-positioning. Interatomic interactions are modeled by the Tersoff potential. The solution procedure for problems with large atom displacements is controlled by the Newton-Raphson iteration procedure with a force relaxation parameter based on displacement length estimation.

[nisidate-04:2013] Y. Nishidate. A generalized ray equation and its solutions for ray-tracing in anisotropic inhomogeneous media. In *OSA Technical Digest (Imaging and Applied Optics, Adaptive Optics: Methods, Analysis and Applications)*, page JW2A.4, Arlington, Virginia, USA, 2013. Optical Society of America.

The geodesic equation, with dielectric tensor as its metric tensor, can be interpreted as the generalized ray equation, and it was employed for the numerical ray-tracing in optically anisotropic inhomogeneous media.

Another form of generalized ray equation is derived from the Fermat ' s principle under the assumption that transverse coordinates of rays are expressed as a function of optical axis.

[nisidate-05:2013] Y. Nishidate. A ray equation for optically anisotropic inhomogeneous media and its closed-form solutions for estimating ray trajectories. In *Procs. of Frontiers of Nonlinear Physics 2013 (FNP2013)*, pages 237–238, Nizhny, Novgorod, Russia, 2013. Institute of Applied Physics, Russian Academy of Sciences.

For the isotropic inhomogeneous distributions, it is possible to validate the precision of numerical procedure based on discrete inputs, through solving problems which solutions are known in a closed-form. However, less studies are found about those for anisotropic inho-mogeneous distributions. In this study, we obtain a generalized ray equation, and its solutions are derived as the function of optical axis direction.

Academic Activities

[fayolle-03:2013] Pierre-Alain Fayolle, 2013.

Program committee member, Shape Modeling International 2013

[fayolle-04:2013] Pierre-Alain Fayolle, 2013.

Reviewer, Computer Aided Design

[fayolle-05:2013] Pierre-Alain Fayolle, 2013.

Reviewer, Computer Graphics International 2013

[fayolle-06:2013] Pierre-Alain Fayolle, 2013.

Reviewer, Computer and Graphics

Ph.D and Others Theses

[fayolle-07:2013] Satoshi Hotta. Metamorphosis between discrete point-sets, University of Aizu, 2013.

Thesis Advisor: Pierre-Alain Fayolle

[fayolle-08:2013] Yutaro Ono. Real-time water height-field simulation using the shallow water equations, University of Aizu, 2013.

Thesis Advisor: Pierre-Alain Fayolle

[nisidate-06:2013] Fumiya Tajima. Graduation Thesis: An adaptive element subdivision algorithm for efficient finite element analysis, University of Aizu, 2013.

Thesis Advisor: Y. Nishidate

[nisidate-07:2013] Ryo Namekata. Graduation Thesis: Street View by WebGL, University of Aizu, 2013.

Thesis Advisor: Y. Nishidate

[nisidate-08:2013] Hikaru Abe. Graduation Thesis: Performance Comparison of WebGL and OpenGL in 3DCG Rigid Body Simulation, University of Aizu, 2013.

Thesis Advisor: Y. Nishidate