PHD PROJECT SCIENTIFIC COMPUTING/ILLUMINATION OPTICS

Optimal transport for optical design

The Department of Mathematics and Computer Science of Eindhoven University of Technology has a vacancy for a PhD-student in its Centre for Analysis, Scientific computing and Applications (CASA). CASA comprises the chairs Scientific Computing (SC) and Applied Analysis (TA). CASA's major research objective is to develop new and to improve existing mathematical (both analytical and numerical) methods for a wide range of applications in science and engineering.

Background

In the lighting industry a revolution is taking place. Traditional light sources like incandescent, halogen, gas discharge are being replaced by (light emitting device) LED technology. This new source technology allows the use of more advanced optical solutions. It is the topic of this project to create new methodologies to compute optics that will further enhance the properties of LED lighting. For example, this project will allow the lighting industry to develop new optical designs with less glare, improved efficiency and new light effects.

The optics applied in illumination is nonimaging, in contract to, e.g., a camera lens which is imaging. In nonimaging optics we study the transfer of light from a source to a target. A key problem is to design optical systems such that a given intensity at the source is converted to a desired intensity at the target. The goal of this PhD project is to develop computational methods that can achieve this.

Project description

Consider an optical system consisting of a source (LED), emitting light at a certain illuminous intensity, an optical surface (either a lens or a reflector) and a target screen (e.g. a road or a wall), receiving light at a desired intensity. For the light transfer conservation of energy holds, i.e., the total power emitted by the source equals the total power received by the target.

The transfer of the energy from source (LED) to target can be interpreted as a (mass) transfer problem: given a (mass) density function f defined on a space X and a density g defined on Y, find a mapping T, referred to as the transport plan, such that the total mass contained in X equals the total mass in Y. In other words, the integral of f over X is equal to the integral of g over Y. In optics, the functions f and g represent the intensities at source and target, respectively.

The transport plan requires some effort, which is modelled by a certain cost function $c = c(x, y)$ defined as the cost to transport one unit of mass from $x \in X$ to $y \in Y$. The combined problem is referred to as the optimal (mass) transport problem and is a classical problem in mathematical analysis. Solution of the optimal transport problem requires numerical methods, which are still hardly available.

Currently, there are two possible approaches to solve the optimal transport problem numerically. The first one is based on the quadratic cost function $c(x, y) = |x - y|^2$.

In this case it can be proven that T is the gradient of some potential u, that satisfies the Monge-Ampère equation, which is a nonlinear elliptic PDE. Advanced numerical solution methods exist for this equation, to compute its convex solution. The second option is the fluid dynamics approach recently developed by Benamou and Brenier. The key idea is to embed the optimal transport problem in a time-dependent minimization problem, giving rise to a geodesic problem. This approach requires the solution of the equations of fluid flow. Numerical methods for the second approach are still in its infancy.

In this project the following aspects can be investigated. What is an appropriate cost function? Can we derive one based on physical principles? Can we compute more solutions of the Monge-Ampère equations than only the convex one? Numerical methods based on the fluid dynamics formulation should be developed and improved. Moreover, they should be compared to an available Monge-Ampère solver. Is it possible to extend the previous to more complex systems, such as non-point light sources?

This PhD research will be executed in close cooperation with the world leader in lighting: Philips Lighting. The project is embedded in a cluster of projects related to illumination optics and the candidate is expected to work closely with the other PhD students and to be present several days a week at Philips Lighting. This will allow the candidate to have a strong interaction with the engineers that will use the tools after the project has been finished.

As a PhD student your tasks are the following:

- Perform scientific research in the described domain;
- Present results at international conferences;
- Publish results in scientific journals;
- Participate in activities of the group and the department;
- Assist SC-staff in teaching undergraduate and graduate courses (at most 20 % of the time).

Requirements:
We are looking for talented, enthusiatic PhD candidates who meet the following requirements:

- An MSc in (applied) mathematics, physics or a related discipline with a strong background in computational physics;
- Experience with Matlab and preferably C or C++;
- Creative, pro-active team player with good analytical skills;
- Good communicative skills in English, both written and oral.

Appointment and salary:
We offer:

- A full-time appointment for a period of four years, with an intermediate evaluation after nine months;

- A gross salary of €2,062 per month in the first year increasing up to €2,638 per month in the fourth year;
- Support for your personal development and career planning including courses, summer schools, conference visits, etc.;
- A research position in an enthusiastic and internationally renowned research group;
- A broad package of fringe benefits (e.g. excellent technical infrastructure, saving schemes, excellent sport facilities, and child daycare).

Information
More information:

- About the project, please contact dr.ir. Jan ten Thije Boonkkamp (TUE), email: j.h.m.tenthijeboonkkamp@tue.nl, tel. +31402474123 or dr.ir. Wilbert IJzerman (Philips), email: wilbert.ijzerman@philips.com, tel. +31610183927.
- About employment conditions, please contact mrs. Corlien van Dam, email: pzwin@tue.nl.

Application
The application should consist of the following parts:

- A motivation letter;
- A Curriculum Vitae;
- Copies of diplomas and a list of grades of your studies;
- Names and addresses of two referees;
- Proof of English language skills (if applicable).

Deadline for application: November 15 2013