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CGI-for-Film: Final Publishable Summary

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The main *scientific objective* of the project is to help establish advanced lighting simulation, namely global illumination, as a common tool for image rendering in the film industry.

The research executed in pursuit of this objective is a part of the *training activities* of the Fellow, with the main goal of acquiring necessary competencies to help develop a successful computer graphics research group at Charles University, Prague.

Motivation

In spite of the tremendous advances of computer graphics, an attentive observation of some of the computer-generated animated films and special effects produced before 2008 and even today reveals a striking lack of visual realism. Among other reasons, the limited realism is due to the simplistic lighting simulation algorithms often ignoring global illumination. If global illumination is used at all, then usually only on objects with simple materials, since the performance of many global illumination algorithms is severely crippled in presence of objects with realistic and complex appearance. This has a negative impact on the visual realism. The prevailing reluctance to using global illumination in film production was due to *low productivity* caused by slow rendering with global illumination, and *limited artistic control* of global illumination.

Scientific Objectives

The main scientific objective of the project was to develop novel algorithms and tools for global illumination rendering that would shorten the production cycle for computer-generated film shots, make the production cheaper, and last but not least, make artists' work more enjoyable. Achieving these goals would ultimately establish global illumination as a common tool for image rendering in the film industry, thereby improving the visual fidelity of the generated images. Improved realism in acceptable computation time could eventually open up new applications for computer-generated visual content. These are the main socio-economic reasons for carrying out the proposed research.

To achieve this overall scientific objective, the following partial objectives were addressed: (1) Improve the efficiency of global illumination algorithms, especially in complex scenes featuring objects with complex materials (e.g. glossy); (2) reduce the stalls in cinematic lighting design; and (3) design an easy-to-use interface to give artists greater control over global illumination.

Training Objectives

The central training objective of the project was that the Fellow acquires, through research and by other means, necessary competencies to later develop a successful computer graphics research group at Charles University, Prague. The importance of this goal stems from the fact that in the near future, computer graphics is likely to play an even more important role in applications such as on-line virtual prototyping, ecommerce, or industrial design. The computer graphics group would educate talented students thereby making Europe more competitive in the global on-line markets.

Brief Work Plan

The project was divided into a two-year Outgoing Phase (August 1, 2008 – July 31, 2010) that the Fellow spent at the Outgoing Host (Cornell University), and a one-year Return Phase (August 1, 2010 – July 31, 2011) that the Fellow spent at the Return Host (Charles University, Prague). The Outgoing Phase was devoted to research and other training activities, while during the Return Phase the focus was shifted on activities related to the development of the computer graphics research group at Charles University.

Work Performed Since the Beginning of the Project and the Main Results

Concerning the **scientific objectives**, significant results have been achieved on all three aforementioned partial objectives of the project:

1. Efficient computation of global illumination in scenes with glossy surfaces

We have investigated multiple lines of research in addressing the efficiency of global illumination in glossy scenes: *illumination caching, many-light methods,* and *optimal connection of light paths*. In the first category, we have developed a novel *spatial-directional radiance caching* technique, which performs well on highly glossy surfaces where the previous caching methods fail. More effort was invested into many-light methods. First, we have proposed the *virtual spherical light*, a novel mathematical formulation which preserves illumination energy on glossy surfaces. Second, we have developed a many-light method that splits light transport into global and local parts, which allows simulating sharp glossy reflections efficiently. In the last category (light path connection), we have proposed a robust combination of path tracing and progressive photon mapping that can render a wide range of complex scenes with little parameter tweaking.

2. Reduction of stalls in lighting design

We have made two contributions on this topic. First, we have proposed an accelerated algorithm for pre-computation and compression of light transfer matrices that reduces the latency before the lighting design session can start. Second, we have performed a formal evaluation of users' ability to perform lighting design tasks using various progressive rendering algorithms.

3. Artistic control of global illumination

To address the flexibility of global illumination, we have developed a comprehensive and intuitive representation for artistic control of global illumination.

Significant achievements in **dissemination activities** include (1) Publications in top-ranked journals (ACM Trans. Graph., Comp. Graph. Forum) and presentations at prestigious conferences; (2) book on practical aspects of global illumination in film production authored by the Fellow; (3) course on global illumination in film production and real-time graphics co-organized by the Fellow and presented at the ACM SIGGRAPH conference; and (4) invited talks at a number of prestigious research institutions in Europe.

Concerning the **training objectives**, the Fellow has made progress both in training through research and in additional training in hard skills (collaboration on a project concerned with appearance measurement and modeling, attendance of graduate-level courses at Cornell University) and in soft skills (participation in a leadership development program, teaching excellence workshops, grant writing seminars, entrepreneurship lectures, and lectures on the ethics of scientific writing).

The **integration activities** in the Return Phase were aimed at the **development of the computer graphics research group** at Charles University. A logo and web pages of the group were created (http://cgg.mff.cuni.cz/). The group's visibility was enhanced by organizing the prestigious Eurographics Symposium on Rendering (http://egsr2011.mff.cuni.cz/). The Fellow taught new courses to get in touch with the students at Charles University and motivate them to pursue research in CG - as a result, three new Ph.D. students are joining the group under the Fellow's supervision. The Fellow took a leading role in the preparation of the accreditation of an independent computer graphics doctoral study program at Charles University. To secure the future of the group, the Fellow participated in writing a number funding proposals.

Conclusions

The results achieved represent a significant contribution to the project's scientific objectives. A number new solutions and improvements have been proposed and tested, that can be integrated by the CG production houses into their software pipelines. The work done within the project has consolidated the Fellow as an independent researcher and research leader. The activities carried out in the Return Phase have contributed the development of the computer graphics group at Charles University, thereby achieving the overall objective of the project.