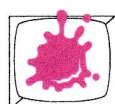


Proceedings of the
23rd Central European Seminar
on Computer Graphics

April 28 - 30, 2019
Smolenice, Slovakia



Institute of Visual Computing & Human-Centered Technology
TU Wien



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OESTERREICHISCHE
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Welcome to CESC G 2019!

This book contains the proceedings of the 23rd Central European Seminar on Computer Graphics, short CESC G, which continues a history of very successful seminars. Again this year, this proceedings have an ISBN (978-3-9504701-0-9) and will therefore remain retrievable as long as there are libraries.

The long history of CESC G has started in 1997 in a medium-sized lecture room in Bratislava, bringing together students from Bratislava, Brno, Budapest, Graz, Prague, and Vienna. The idea found wide appraisal and the seminar moved to the beautiful castle in Budmerice, where it was held for twelve years, constantly/ growing in size and attraction. It was just in 2006 and 2011 that CESC G had to take a detour to Častá-Papiernička Centre, and Viničné. Since 2012 we moved to the beautiful castle in Smolenice which is the conference centre of Slovak Academy of Sciences.

Who are the CESC G heroes who made this year's seminar happen? In no particular order – because many people were involved equally – we would like to thank the organizers from Vienna: **Michael Wimmer**, Max Höfferer, Hiroyuki Sakai, Christian Freude and Werner Purgathofer. Special thanks goes to **Martin Ilčík** for the excellent preparations and on-site organization. **Markus Steinberger**, Daniel Mlakar and Martin Winter from Graz coordinated the reviewing process. We are very thankful to the local CESC G organizers from Bratislava, Adriana Bosáková, Lukáš Hudec, Zuzana Berger-Haladová and **Andrej Ferko**, always an inspiration to CESC G. Stanislav Griguš again produced awesome promotion videos and graphics. Very important is the involvement of all our project partners at their home universities where they promote the event and prepare own students for the seminar. Many thanks goes to our main partners: Budapest University of Technology and Economics, Czech Technical University in Prague, Sarajevo University and West Pomeranian University of Technology in Szczecin.

The main idea of CESC G is to bring students of computer graphics together across boundaries of universities and countries. We focus on sustainable academic and research development in the field of visual computing in Visegrad Countries and Austria. Our mission is to support undergraduate talents in their future careers. We have 14 participating institutions with 22 students presenting their excellent work, two invited talks and an alumni discussion. We welcome groups from Bratislava (CU and STU), Slovakia; Brno (MU and VUT), and Prague (CU and CTU), Czech Republic; Budapest (BME), Hungary; Graz and Vienna (TU and VRVis), Austria; Szczecin, Poland; Lausanne, Switzerland, Cambridge, United Kingdom, and Sarajevo (UnSa), Bosnia and Herzegovina.

We assembled an International Program Committee of 13 members, allowing us to have each paper reviewed by two IPC members. Students also cross-reviewed their papers. We would like to thank the members of the CESC G 2019 IPC for their feedback:

Jiří Bittner
Daniel Cornel
Eduard Gröller
Martin Kampel
Barbora Kozlíková
Jaroslav Křivánek
Rafał Mantiuk

Helge Rhodin
Selma Rizvić
Markus Steinberger
László Szirmay-Kalos
Michael Wimmer
Pavel Zemčík

The reviewing process was further supported by: Clemens Arth, Jan Egger, Ivo Kondapaneni, David Kouřil, Katharina Krösl, Renata Raidou, Tobias Rittig, Daniel Mlakar, Maria Schimkowitsch, Attila Szabo, Martin Winter.

The first invited talk “Visual Geo-Localization and Camera Pose Orientation for Computational Photography” will be held by Martin Čadík from Brno University of Technology. The second invited talk by Markus Steinberger from TU Graz, Austria, will be about “On the dynamics of GPU execution: Software Rasterization, Geometry Processing, and Dynamic Graphs”. Martin Ilčík from TU Wien will train the students “How to pitch” and will also guide them in the second workshop called “Leadership for Superheroes”.

With the 20th anniversary of the seminar in 2016, Martin Ilčík initiated the CESC G EXPO project. Again this year, 16 companies and research institutions specialized on visual computing will present their innovative products in an interactive exhibition. The exhibitors are:

Bohemia Interactive Simulations, Prague
Capturing Reality, Bratislava
Escape Motions, Piešťany
Grand Beats Production, Tomášov
Grindstone, Košice
Hangar 13, Brno
Pixelstore, Vienna
Procedural Design, Vienna

Render Legion, Prague
Nanographics, Vienna
Vectary, Bratislava
VR Group, Brno
Photoneo, Bratislava
VRgineers, Prague
VRVis, Vienna
Warhorse Studios, Prague

The organization of a seminar where there are only low expenses for the students requires funding. We are very thankful to the partners of CESC G 2019:

- **International Visegrad Fund**,
- **VRVis**, Research Center for Virtual Reality and Visualization,
- **Capturing Reality**, the photogrammetry solution for everybody,
- **Photoneo**, 3D robot vision for flexible automation,
- **OCG**, the Austrian Computer Association,
- **SISp**, Slovak Society for Computer Science,
- **Procedural Design**, massive content creation.
- **Two Minute Papers**, awesome research for everyone.

The electronic version of these proceedings is available at <https://cescg.org/library/>.

April 2019, Martin Ilčík, Markus Steinberger, Daniel Mlakar, Martin Winter,
Michael Wimmer

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3D Motion Blur For PET Using GPGPU

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Budapest University of Technology and Economics
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Abstract

Computing motion blur is important not only in video games and movie rendering, but also in physical simulations where the effect of the movement has to be calculated and compensated. One such application is dynamic Positron Emission Tomography (PET), which is one of today's most important medical imaging techniques. When studying neurological disorders like epilepsy with PET, the involuntary movement of the patient during a seizure can ruin the examination results. Because of this, motion compensation should be incorporated into the reconstruction process. When the movement is rapid, accurate motion blur presents a challenge even if only 2D image space results are needed and hardware capabilities can be exploited. However, in the case of PET, the blurred result is expected in the 3D space. Blurring the motion of a 3D object in the 3D space can be done by dividing its bounding box into homogeneous voxels and tracking the path of each voxel independently. As low execution time is crucial, simplifications must be applied at the expense of accuracy. The solution proposed in this paper approximates the path of each voxel with a sequence of line segments. The segments can then be sampled by properly adapted 3D line drawing algorithms such as the Antialiased Bresenham Algorithm. Implementation is accelerated by parallel execution on GPU using the CUDA platform.

Keywords: 3D, Motion Blur, Line Drawing, Antialiased Bresenham, Positron Emission Tomography, PET, CUDA, GPU, GPGPU

1 Introduction

Dynamic Positron Emission Tomography (dynamic PET) analyzes the dynamic nature of biological processes through observing the accumulation and emptying of drugs in organs [10, 14, 15]. At the beginning of the examination, a small amount of radioactive material called radiotracer is injected into the patient, which then spreads across the body and gets absorbed into the tissues. The emitted radiation is detected by the tomograph and the

3D spatial distribution of the radiotracer is reconstructed. Cells with rapid metabolism, such as cancer cells, absorb more tracer and thus appear as bright spots on the image.

During reconstruction, the measured volume containing the body of the patient is divided into a 3D grid of homogeneous voxels. The task is to determine the amount of the radiotracer in each of the voxels based on the emission detected by the detector ring surrounding the volume.

When studying neurological disorders like epilepsy, the self-motion of the patient is often unavoidable, which can ruin the examination results. The problem can be attacked by measuring real-time the movement using markers [7] and incorporating the gathered information into the reconstruction process. The solution we are proposing uses the information about the movement to apply motion blur on the voxel array during measurements.

Object position at any moment can be described with a geometric transformation consisting of translation and rotation. As motion is a change in position, movement is also described by a geometric transformation in the form of a translation vector and a quaternion for rotation.

The input of the motion blur computation is the voxel array containing the current estimation of the number of radioactive decays that occurred in the voxels and the geometric transformation determined using the markers on the patient. The input array is considered to be moving along with the patient. During motion blur, the task is to map the voxels of this moving array into a motionless destination array of the same size. The output is the unmoving array with voxel activities mapped from the moving array.

The classical solution to the problem is to calculate the position of each moving voxel's center point in very small time steps, i.e. determine which voxels of the motionless array does the currently examined moving voxel overlap. This means interpolating the geometric transformations describing object motion and then applying the resulting transformation at every time step. Translation vectors are interpolated linearly and the quaternions using Spherical Linear Interpolation (SLERP, Figure 1).

When accuracy is an important aspect, each voxel path should be sampled at a sufficiently high frequency relative to the motion dynamics. Furthermore, since in most cases the voxels of the moving and the motionless arrays overlap each other only partially (Figure 2), additional points

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