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Multi-Threaded Integration of HTC-Vive and MeVisLab

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ABSTRACT

This work presents how Virtual Reality (VR) can easily be integrated into medical applications via a plugin for a medical image processing framework called MeVisLab. A multi-threaded plugin has been developed using OpenVR, a VR library that can be used for developing vendor and platform independent VR applications. The plugin is tested using the HTC Vive, a head-mounted display developed by HTC and Valve Corporation.

Keywords: Virtual Reality, HTC Vive, Valve Corporation, Threads, MeVisLab, Module.

1. DESCRIPTION OF PURPOSE

Virtual Reality (VR) [1]-[3] is increasingly used in entertainment [4]-[6], training [7], simulations [8], [9] and also in the medical domain [10]. It has been used in applications such as the therapy of phantom limb pain [11], the rehabilitation of stroke patients [12], the treatment of autistic individuals [13] or the training of wheelchair usage for patients suffering from spinal cord injuries [14]. In 2002, Morgan et al. [15] showed how VR can improve the learning success of medical students when it comes to skills in clinical routines [16]. Even higher potential for VR may be in visualization of datasets acquired with computed tomography (CT) or magnetic resonance imaging (MRI) [17]. Farahani et al. [18] have demonstrated how to explore pathology data in a head-mounted display (Oculus Rift). Others have investigated on how VR can be used in surgery [19], [20].

Previous work in our group [21], [22] demonstrated how to integrate the HTC Vive head-mounted display [23]-[26]with the medical image processing framework MeVisLab (http://mevislab.de) [27]-[35] using OpenVR (https://github.com/ValveSoftware/openvr). This approach leverages the larger tracked space of the Vive for a more flexible inspection of medical data. In this paper, we present a multi-threaded implementation of the Vive-MeVisLab integration, which significantly improves performance. The multi-threaded approach allows continuous manipulation of the MeVisLab dataflow network while the VR experience keeps running. Changes applied in MeVisLab can be transferred to the VR view at any time. This opens up advanced medical image processing operations like medical segmentations [36]-[45] or simulations [46]-[48] to be triggered within a VR interface.

2. METHODS

Data – In order to develop, test and evaluate our module, we have used the dataset provided by Gall et al. [49]. It consists of several high resolution CT scans from real patients. A single scan is made up of a few hundred slices, each of them containing 512x512 voxels. They vary in anatomy and pathology. To ensure that our module is suitable to clinical routine, we have not downsampled or altered the scans, but rather visualized raw data in VR.

Implementation – The overall goal of the HTC-Vive MeVisLab module is to connect MeVisLab to VR (Figure 1). Whenever triggered in MeVisLab, the integration module retrieves the current medical dataset and forwards it to the VR view. A back channel communicates the position orientation of the headset to MeVisLab.

The implementation of the HTC-Vive MeVisLab module consists of three parts. The first part is responsible for wrapping the VR application into a module that can be used by MeVisLab. The module spawns multiple threads to enable a concurrent execution of MeVisLab and the VR view. The second part generates a stereoscopic rendering (for left and right eye) of the medical data into an off-screen buffer, using Phong shading [50]-[52] in OpenGL [53]. The third part outputs the buffer to the VR headset using OpenVR.

Network – MeVisLab uses dataflow networks (Figure 2) to connect modules for image processing and other purposes. The VR integration module expects a 3D model. For example, we can connect a WEMLoad module to load a DICOM dataset [54]-[56] and convert it into a 3D mesh internally in the VR integration module. If desired, additional modules can be inserted to modify (WEMModify) the data or display it for debugging inside MeVisLab (SoWEMRenderer).

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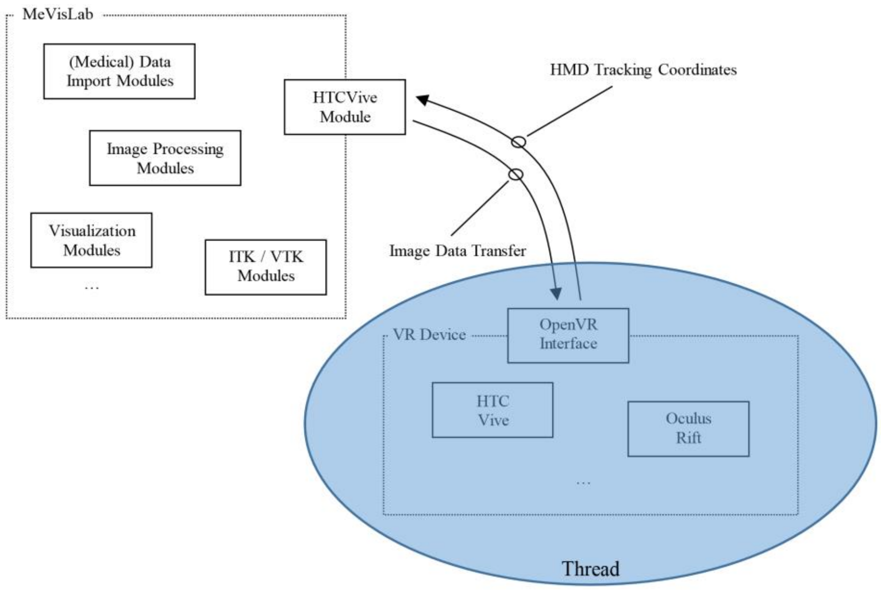

Fig. 1: High-level workflow diagram showing the communication and interaction between MeVisLab and the HTC Vive via OpenVR encapsuled into a dedicated thread.

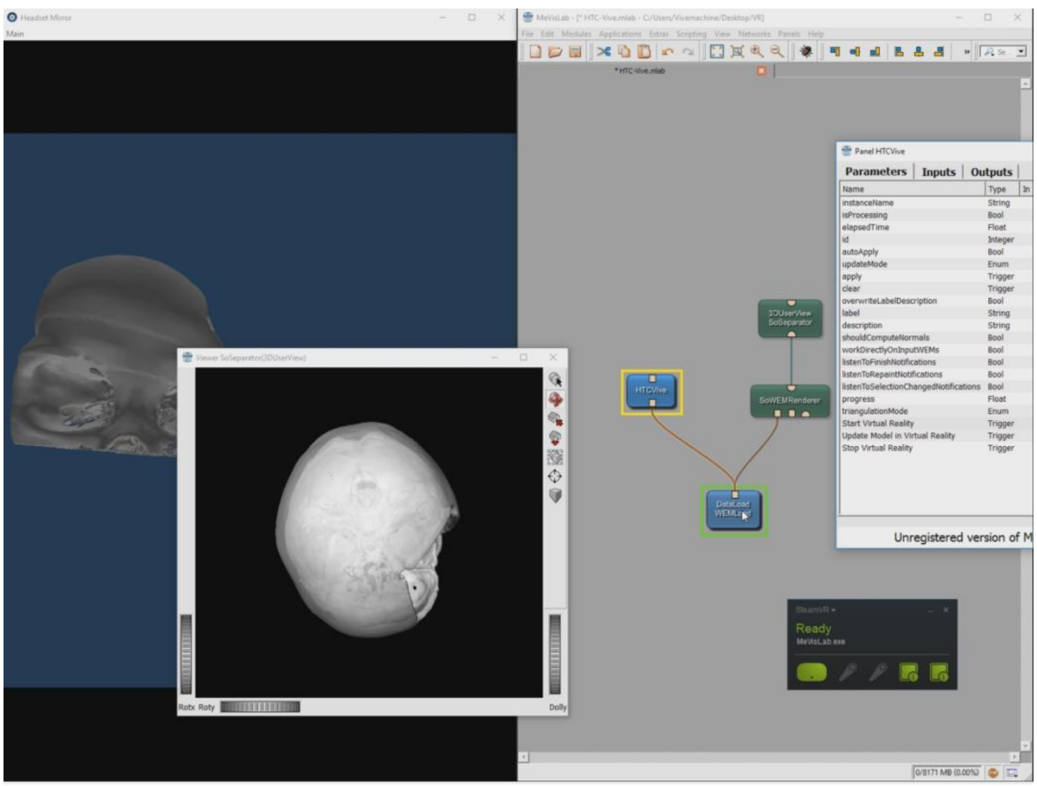

Fig. 2: A simple MeVisLab network with the multi-threaded HTCVive module, showing interface and parameters on the right side. The left side shows a headset mirror window in the back and a standard 3D viewer window from MeVisLab.

3. RESULTS

The goal of this work was to show the feasibility of an enhanced multi-threaded integration of VR into MeVisLab. A MeVisLab module that allows users to visualize medical 3D image data in Virtual Reality has been implemented (Figure 3). The module is able to render models from various file formats such as Object File Format, Wavefront, Polygon File Format, Standard Tessellation Language, VRML or Winged Edge Mesh. When loaded into Virtual Reality, models are automatically scaled and placed in the center of the viewport. In addition, the module illuminates the rendered scene using the Phong shading model.

The multi-threaded design allows the simultaneous use of the MeVisLab interface. This allows a user to apply image processing operations provided by MeVisLab [57]-[63] to the model before reloading it into Virtual Reality again. The module offers a possibility to mirror onto screen what a user sees in Virtual Reality. The module has been developed and tested under Microsoft Windows 8.1 Enterprise Edition. In addition, MeVisLab SDK Version 2.8.1 for Windows Visual Studio 2015 X64 (http://www.mevislab.de/download) has been used. For rendering medical 3D image data, OpenGL 4.0 (https://www.opengl.org/) has been used in combination with GLEW 2.0.0 (http://glew.sourceforge.net/), GLFW 3.2.1 (http://www.glfw.org/) and GLM 0.9.8.4 (http://glm.g-truc.net/0.9.8/index.html). For visualizing the rendered 3D scene in Virtual Reality, the OpenVR SDK Version 1.0.2 (https://github.com/ValveSoftware/openvr) has been used. Development and testing have been done on a desktop PC with an Intel Core i7-3770 CPU @ 3.40GHz, 16 GB RAM and a NVIDIA GeForce GTX 970 graphics card.

The module has been tested using several medical scans with different anatomy and pathology. All tests resulted in a smooth visual experience in Virtual Reality. The source code is freely available from GitHub (https://github.com/simon-gunacker/vive).

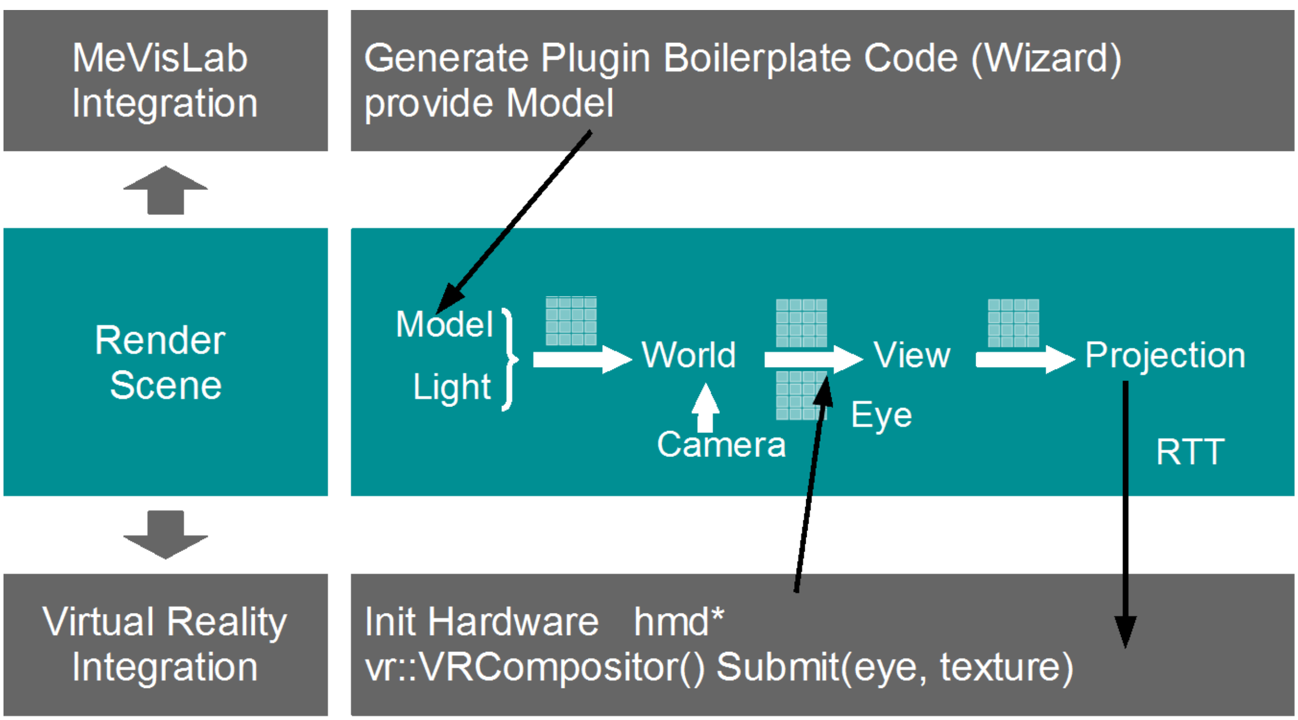

Fig. 3: Diagram showing the three parts of the implementation of the HTC Vive MeVisLab plugin: the first part is responsible for integrating the plugin into MeVisLab providing a 3D model to the second part, which is then responsible for rendering a scene. The third part sets up the VR environment, provides the rendering part with information about the user's position in VR and finally visualizes the rendered scene in VR.

4. CONCLUSIONS

In this contribution, we presented a MeVisLab module enabling the simultaneous use of MeVisLab an immersive Virtual Reality view via OpenVR. The module can be integrated into any network created by MeVisLab. As these networks are used to perform various tasks, the HTCVive MeVisLab module can be a good visual support, whenever it comes to the inspection of 3D medical data. The main achievements of this work are:

- The successful thread-based integration of the HTC Vive into MeVisLab;
- Making the source code available to the research community.

Future work will involve the deeper integration of Virtual Reality into MeVisLab: by improving the communication from MeVisLab to Virtual Reality, modifications performed in MeVisLab could be rendered to Virtual Reality in real-time. Moreover, different Virtual Reality systems provide handheld controllers to interact with the virtual world [64]-[66]. Integrating these controllers into the module would allow users to perform some operations on the model in Virtual Reality. These operations could reach from simple geometric transformations, such as moving, scaling or rotating the model to operations that have more clinical meaning, such as fitting an implant [67], [68] or performing virtual surgery on the model [69]. The integration of controllers could lead to further improvements regarding the communication from Virtual Reality to MeVisLab: Modifications on the model in Virtual Reality could be communicated to and adopted by MeVisLab in real-time, as a user might perform some operations on the model in Virtual Reality. Aside from these functional improvements, the module could be tested with other Virtual Reality systems such as the Oculus Rift [70]-[73]. An additional and promising improvement may be support for Google Cardboard [74]-[78], which uses inexpensive smartphones as displays. The module could also be integrated into other medical imaging platforms. We believe that integrating Virtual Reality into clinical routines has high potential to improve medical procedures.

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A video demonstrating the thread-based integration of the HTC Vive into the medical platform MeVisLab is available on YouTube: https://www.youtube.com/c/JanEgger/videos

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