BVS-Vis: A Web-based Visualizer for BloodVoyagerS

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ABSTRACT

BloodVoyagerS (BVS) is an ns-3 module that simulates the global movement of nanobots in the human body. The BloodVoyagerS Visualizer (BVS-Vis) is a multi-platform visualization tool for result files of BVS. BVS-Vis shows the distribution of the simulated nanobots over time in a three-dimensional cardiovascular model. The animation can be rotated, moved, zoomed in and it is possible to navigate through different time steps. For a quick interpretation of simulation results, a heat map of the nanobots concentration can be generated via post-processing. BVS-Vis is available as a website and as a complete docker-compose setup. It increases the workflow with BVS significantly and enables quick analysis of simulation results.

CCS CONCEPTS

• **Networks** → *Network simulations*; Mobile ad hoc networks; Wireless access points, base stations and infrastructure; • **Applied computing** → *Life and medical sciences*; • **Hardware** → **Emerging simulation**.

KEYWORDS

Visualization, Nanonetworks, Simulation, Medical Application, Nano medicine

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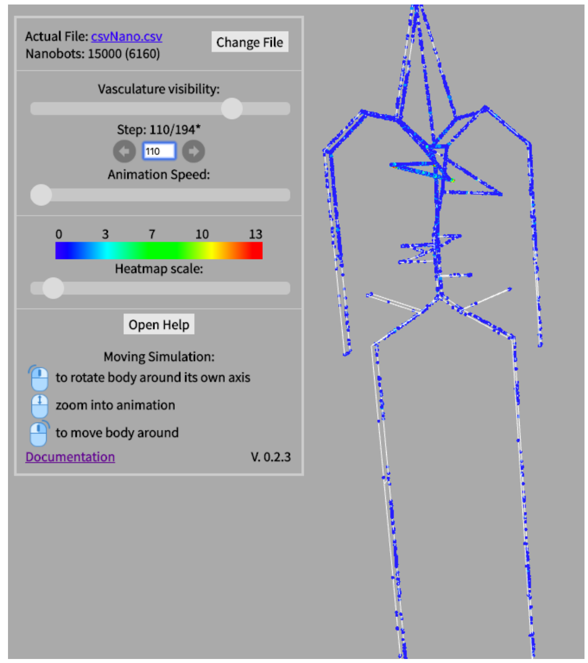

Figure 1: BVS-Vis animated distribution of 15 000 nanobots, 110 seconds after injection into the right forearm (vena basilica cephalica).

1 INTRODUCTION

Medical nanonetworks are networks of nanosized devices envisioned to play a major role in the future of medicine. Their potential in healthcare applications is basically unlimited. It ranges from intrabody health monitoring and drug delivery systems over immune system support mechanisms, to artificial bio-hybrid implants [1]. Simulation is a key component to develop and analyze such medical nanonetworks. Several simulators exist up to date [3]. In 2018 we developed the simulator BloodVoyagerS (BVS) [5] as an ns-3 module to simulate the continuous global movement of objects in the human body, which hasn't been done in other existing simulators. BVS main purpose is to model the work environment of medical nanobots. It is going to be part of the holistic Nanosimulation Framework Human (NFH) [4] which enables the modelling of whole healthcare application scenarios. To comprehend the simulated processes visualization is an important factor. BVS was lacking such a direct visual representation since the simulators result file requires post-processing [2]. BVS-Vis[1] closes this gap and facilitates post-processing and visualization at once. BVS-Vis is a web-based application that processes the BVS result file, and animates every simulation step in the three-dimensional model of the simulated vascular system. There are two options on how to use BVS-Vis. The simplest way is to go to the website[2] and directly upload a

[1] https://github.com/RegineWendt/BVS-Vis
[2] https://bvsvis.itm.uni-luebeck.de/

result file which gets visualized right away. The more sophisticated option is to use our code from github[1] with a complete docker-compose setup to build BVS-Vis locally. With the github version, the post-processing function is included and a heatmap feature is available.

2 VISUALIZER

Figure 1 shows the distribution of 15 000 nanobots, 110 seconds after an injection as seen in the visualizer. The heatmap feature is enabled, so that the color of the nanobots indicates the number of nanobots in close range from each other. To the left, the control panel is depicted which points to most of the features discussed in this Section.

2.1 Features

Data format of input data. BVS-Vis takes the CSV result file from BVS as input data. The CSV file describes a single nanobot position per row. A row contains the nanobots ID, the x, y, and z coordinates, the simulation timestamp, the ID of the vessel and lastly the stream of the current vessel, all separated by a comma.

When the simulator is running, the upload of a new CSV file is always possible. On opening the website, a default result file is set initially, while in the docker-setup, the output file is automatically imported. BVS-Vis streams the input files and can therefore handle large files and supports compressed files as well. However, the jump function is limited in large streamed files. A python script to compress the CSV file is included. If a compressed file is loaded, a heatmap with the actual nanobot density gets displayed.

Visualization. The nanobots are represented within a coordinate system and the underlying vascular system is shown. The visibility of the vasculature can be adjusted. The simulated body can be rotated, moved around or zoomed in.

Temporal representation. The simulation runs automatically or step by step and the animation speed can be changed. With a jump function it is also possible to go to a specific time step.

Heatmap. The nanobot distribution can be displayed with a heatmap when the CSV file is preprocessed and compressed. The heatmap shows the concentration of nanobots in one area. The degree of coloring can be changed manually. Figure 2 shows the heatmap feature in more detail. The animation is zoomed in to the area of the left heart chamber. The heatmap is set as shown in Figure 1. In the vena pulmonalis (1) and the aorta ascendens (3) the density of nanobots is much lower with 0–4 nanobots per point, than in the left heart chamber (2), with a density of 7–14 nanobots per point. These differences could not be read out as easily without the heatmap feature.

2.2 Implementation

Since platform-independent software is of great advantage, a Java-based and a web-based solution were examined. A Java based solution, however, was discarded as a possibility

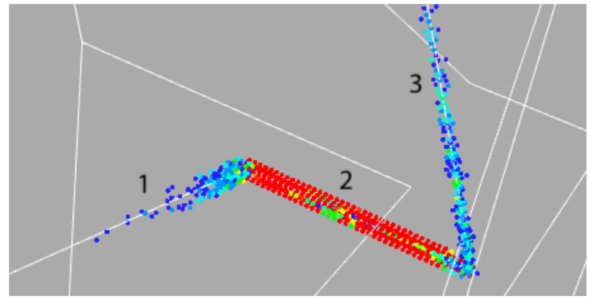

Figure 2: BVS-Vis animated distribution of 15 000 nanobots, 41 seconds after injection into the right forearm (vena basilica cephalica). The numbers indicate the vessel: 1). Vena pulmonalis, 2). Left heart chamber, 3). Aorta ascendens.

because no suitable libraries were available for the visualization. For a locally executable implementation, Javascript was the logical choice as implementation language and the Three.js library was selected for the animation as it has WebGL support and is therefore performant. For the manipulation of HTML pages jQuery is used and Papa Parse for the streaming of the CSV files. In the docker setup, the CSV file gets reduced by 95 % with a python script that omittes unnecessary information like vessel and stream and enables the clustering of nanobots by reducing the accuracy of the coordinates.

3 SUMMARY AND OUTLOOK

Two existing limitations will be addressed in the future. The GPU load that the animation generates on a computer is high and the time jump function is limited in files larger than one gigabyte due to the streaming of the file. Nonetheless, BVS-Vis runs smoothly on current hardware, is platform-independent and works with every common browser. It is maintainable, expandable and third parties are very much invited to contribute through github.

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