MODELLING OF INFLUENCE OF ELECTROMAGNETIC FIELD ON MOVEMENT OF IONS IN THE HUMAN BODY

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Abstract

In this paper we are proposing a method for computer simulation to study the behavior of charged particles in electromagnetic filed. The main application of this method is the visualization of processes when of the electromagnetic field is applied to human body. Some exemplary simulations and their results are presented.

1. INTRODUCTION

Electrical and magnetic fields are often used for treating patients during recovery phase from certain illnesses. However at present time there is a lack of understanding of the exact influence of these methods on human body. Availability of such tools would visualise these processes which would greatly help the physicians to choose the proper positioning of the active devices and also their parameters in order to achieve maximum effect from this kind of treatment.

2. MODELING TARGET

Electromagnetic field has an influence on all kind of tissues. However for the current discussion we will focus our modelling attempts with the extra cellular liquid. Its properties as a medium for transportation of active chemical agents makes it perfect target for assessing effects of the influence of the electromagnetic field. Thus we limit our review only with the soft tissues and presence of the bones is ignored.

3. SIMPLIFIED MODEL OF BODY FLUIDS

As a simplified model of the body fluids we chose fluid saline. There are several types of this fluid used for transfusion [1] but in general it is sterile solution of sodium chloride (salt) in water. Up to 40g of NaCl fully dissolve in 1 L of water. For simplification we will accept that all molecules of NaCl are dissociated to Na^+ and Cl^- ions.

The molecules of water are known to perform Brownian movement. It is generally random of direction and speed, and the average speed correlates to the temperature.

4. PHYSICAL MODEL

The forces generated by electromagnetic field on a charged particle is given by the Lorentz force equation [2]:

$$m\vec{a} = q\left[\vec{E} + (\vec{v} \times \vec{B})\right]$$

where:

- m - is the mass of the particle,
- $\vec{v}$ - is the vector of its speed,
- $\vec{a}$ - is the vector of its acceleration,
- q - it's electrical charge,
- $\vec{E}$ - intensity of the electrical field applied to it,
- $\vec{B}$ - vector of the magnetic induction.

Currently we don't take into account mutual influence of the simple charges. This would improve correctness of the model but for initial visualisation its influence is not a deciding factor.

5. ALGORITHM AND IMPLEMENTATION

Actual implementation of the calculation defined by the Lorenz force equation is given by the algorithm on Fig. 1.

For visualisation it is used SDL library [3]. Simple DirectMedia Layer is a C cross-platform multimedia library designed to provide low level access to the video framebuffer. Thus it provides high performance and portability to different computer platforms.

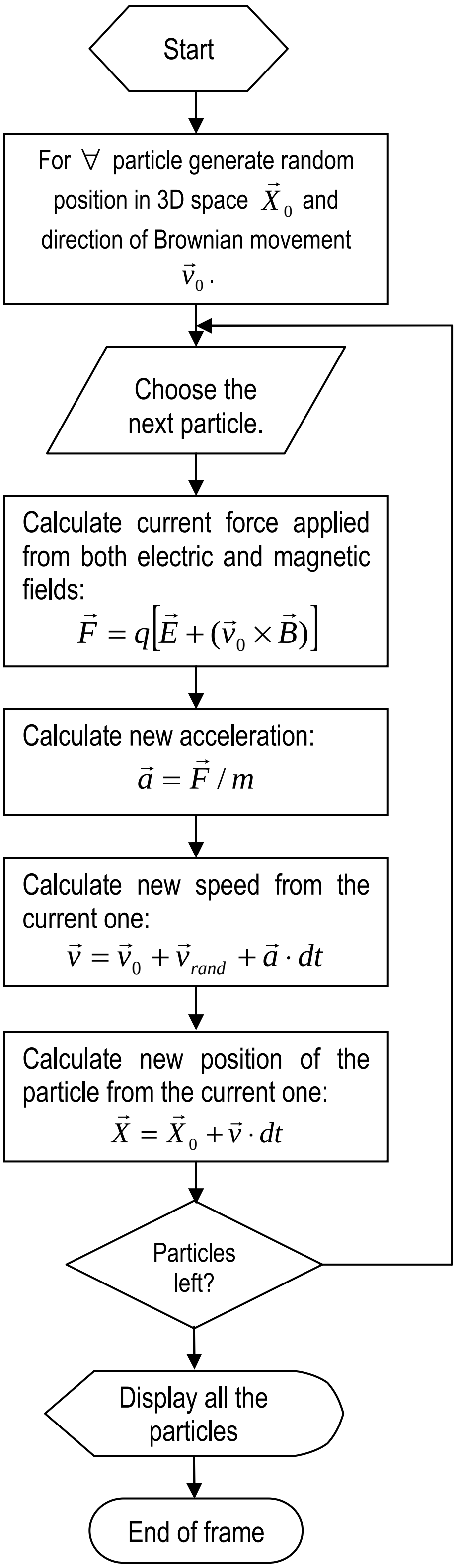

Fig. 1. Algorithm

For vector computation Eigen library is used [4]. Eigen is a C++ template library for linear algebra: vectors, matrices and related algorithms. It is versatile providing all needed operations in an elegant framework. But most of its virtue however is its speed thanks to C+ templates which enable optimisation of the code on multiple levels. Its performance is comparable with the traditionally unbeatable Fortran libraries. Syntax of the calculations is easy to use and intuitive.

Choice of the above two libraries, makes possible a visualisation of a large number of particles in real time on a personal computer.

6. SIMULATION RESULTS

Positions of the particles can be visualised using a 2D projection from their 3D simulated space as shown on Fig.2. This kind of view, although natural doesn't give much information on characteristics or the history of the process.

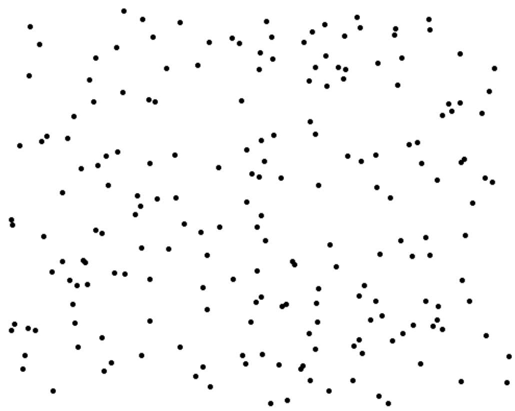

Fig. 2. Real time visualisation of the positions of the particles

Another much better approach is to give to user information of the trajectory of the particles. This method however is only practical for much smaller set of particles. Bigger sets of particles, very fast clutter the screen and make this type of visualization unusable.

As a first example of simulation we chose to use 20 particles put in a closed 3D space in electric field. It is applied using two electrodes, one above and the other bellow the simulated space. Intensity of the electric field $\vec{E}$ is chosen to be constant for the whole volume. The boundaries of the volume make the particles reflect. The result is given on the Fig. 3.

It is clearly visible that main direction of movement is upwards and downwards which corresponds to the direction of the applied electric field.

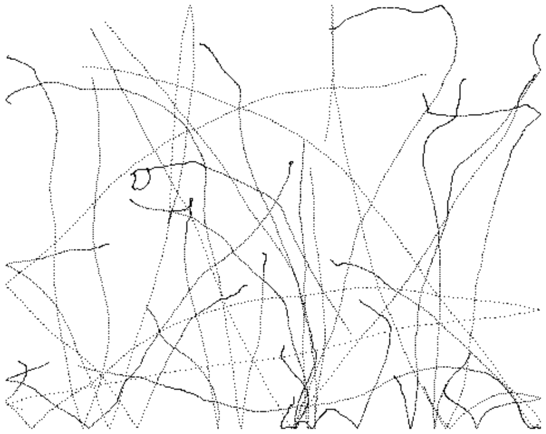

Fig. 3. Visualisation of the trajectory of the particles under constant electrical field

Next, Fig. 4 shows the result of the simulation for a similar setup where the two electrodes are substituted with a point charges. In this case the force is inversely proportional to the square of the distance between point charges and the particle.

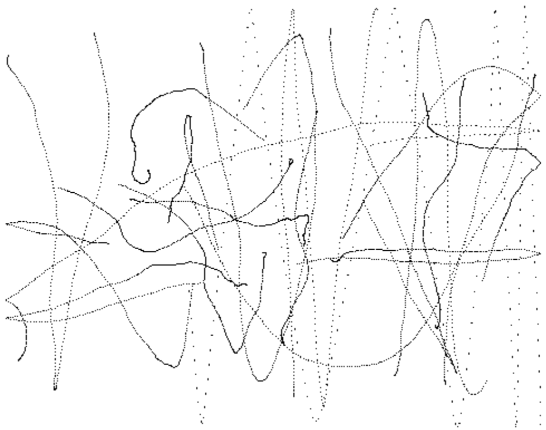

Fig. 4. Visualisation of the electrical field modelled by 1D Columb's law.

It is very well visible that the particles close to the point charges experience the strongest forces due to stronger electric field in proximity of the point charges. On the other hand the particles in the middle are not strongly affected by the electric field and perform quasy-random movement.

In described simulations only electric field is considered. Next step is to include the influence of the magnetic filed as well, which is applied simultaneously to the electric one. On the next, Fig. 5 is shown the result of the simultaneous application of both fields. The electric field is applied using two electrodes, while the coil which generates magnetic field is in front and on the back of the volume on the image. Thus vector of the magnetic filed corresponds to the direction of the viewing.

It is clearly visible that particles follow circular-like trajectories. This is a result of the force applied to them as a consequence of their movement and the magnetic field itself.

Fig. 5. Simultaneous influence of the electric and magnetic fields

Last simulation is of the same nature as the previous one with only one difference – the value of the applied magnetic field is larger. The result is shown on Fig. 6.

Form the figure is visible that larger magnetic induction creates larger force and that leads to trajectories with smaller circles ad much less drift of the particles from their original positions.

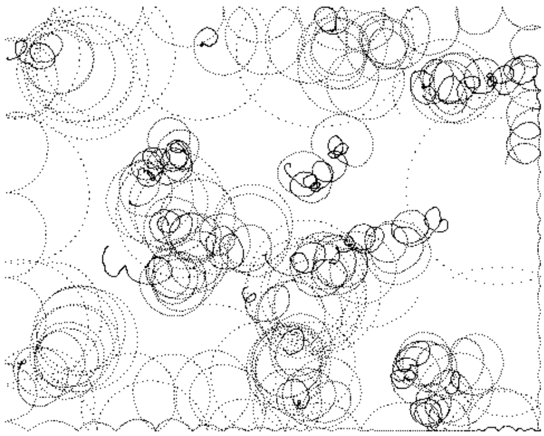

Fig. 6. Simultaneous influence of the electric and magnetic fields – different parameters

All of the given examples show that visual representation of the result of simulation can form intuitive understanding of the influence of electromagnetic field. Change of the configuration and/or the parameters have an easy visible change in particles behaviour.

7. FURTHER DIRECTIONS FOR DEVELOPMENT AND CONCLUSION

Further directions for work includes optimization of the algorithm to simulate larger volumes of particles in real time. Another possibility for speed up the simulation is to use programmable capabilities of modern graphics processing units of the PCs. Simulations like these are very well suited for a parallel computation and can lead to increased speed between one and two orders of magnitude.

Research needs to be done towards better and more intuitive methods of visualisation.

More complex shaped boundary conditions could be used to simulate different body tissues.

Presented simulations and their visualization give the physician outlook of the processes taking place in human body when electromagnetic field is applied. The ability to view, understand and control the treatment would be of great practical interest.

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