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## VISUALIZATION OF EXPERIMENT RESULTS IN SCIENTIFIC E-ARTICLES

*Computers bring brand new abilities to represent data calculated by mathematical models. A simple static figure can't show all the details of 3D model and evolution of a complex physical process, which can significantly limit spreading of scientific results and usefulness of e-article. A present work considers data representation for readers by multimedia web components replacing static figures in e-article. The viewport consists of built-in components of popular Internet browsers, fulfils presented functional and technical requirements, including a support of free media formats. Its user interface structure, similar to the video component, is shown and explained. The content played by viewport is organized in snapshots, which contain arrays of floats and other data. These snapshots are used to update a virtual 3D scene. The scene consists of camera, lights, static and generated meshes including colored quads and arrows for speed field. As result the presented illustration shows implemented viewport with rendered state of a metallurgical process at a specific moment of time. Comparing to existing works it is considered providing audio-comments for the viewport in e-article, which expands circle of its potential readers. The proposed component can play an evolution of 3D field of scalars intuitively controlling the playback including position of a virtual camera. It has two standard modes of playback: automatic and user-dependent — seeking needed moment.*

**Keywords:** interactive data representation; virtual 3D scene; multimedia HTML5 components; academic e-articles.

*Комп'ютери дають нові можливості представляти дані, розраховані за допомогою математичних моделей. Простий статичний рисунок не може відображати всі деталі 3D-моделі та еволюції складного фізичного процесу, що може значно обмежити поширення наукових результатів та корисність електронної статті. У цій роботі розглядається представлення даних для читачів мультимедійними веб-компонентами, що замінюють статичні рисунки в електронній статті. Область перегляду складається з вбудованих компонентів популярних Інтернет-браузерів, відповідає представленим функціональним та технічним вимогам, включаючи підтримку безкоштовних медіа-форматів. Показується та пояснюється його структура інтерфейсу користувача, подібна до відеокомпонента. Вміст, який відтворюється областю перегляду, організований за моментальними знімками, які містять масиви чисел та інших даних. Ці знімки використовуються для оновлення віртуальної 3D-сцени. Сцена складається з камери, джерел світла, статичних та генерованих моделей, включаючи кольорові чотирикутники та стрілки для поля швидкості. Як результат, представлена ілюстрація демонструє реалізовану область перегляду із прорисованим станом металургійного процесу в конкретний момент часу. Порівняно з існуючими роботами розглядається надання аудіокоментарів для області перегляду в електронній статті, що розширює коло його потенційних читачів. Запропонований компонент може відтворювати еволюцію 3D полів, інтуїтивно керуючи відтворенням, включаючи розташування віртуальної камери.*

**Ключові слова:** інтерактивне представлення даних; віртуальна 3D-сцена; мультимедійні компоненти HTML5; академічні електронні статті.

### Problem's Formulation

Invention of the book printing gave magnificent opportunities and new horizons for the science development, including information distribution between scientists even over centuries. One could continue and finish a complex work of other or make generalization of famous solution of problem for other branch of science. Without an academic publishing a contemporary science couldn't be so developed and diverse. A modern science can solve complicated problems and predict an evolution of multifaceted processes in time. A compound multidimensional mathematical model of a complex

dynamical system produces a large amount of data, which needs to be visualized in comprehensible manner. To present such evolution of a process, including 3D models, in article the scientists compelled to place few figures showing considered system states at certain time moments. It increases the count of used pages in the article. Usually the figures are static and reader cannot see the whole 3d model of the system or choose other moment of time. 2D charts are good at visualization of few variables evolution in time. Therefore scientists need new opportunities to publish their research results.

#### **Analysis of recent research and publications**

There are many solutions to the considered problem. Authors of [1] use 3D features of PDF to present models for liver surgery. PDF is a very popular format and is supported by the most Internet browsers, already installed on many user computers, for reading static text and figures.

Authors of the work [2-3] propose “animated figures” to enrich experience of readers. Authors mention increased memory consumption of using such figure because it can contain a large video fragment. Also they talk about distractions that can arise during looping, when after the end video goes to its beginning.

The works [4] review efforts in incorporating of dynamic figures in articles as well as advantages and disadvantages of such embedding. Authors mention nonexistence of international standard for this. They underline an importance of “wider adoption of dynamic figures”.

The authors of paper [5] use a graphic library, which allows him to embed 3D models in PDF without commercial software. They present a multistep explanation how to create 3D figure and reference it in a LaTeX document. Also they list 15 keyboard shortcuts for mentioned graphic library to manipulate 3D model and view. A lot of figures show successful result of the work.

In the paper [6] authors extend default capabilities of 3D PDF for making series of teaching slides. Two modes are proposed for creation of presentation and its viewing. Properties of each slide are stored at XML file.

Author of [7] also use 3D PDF to visualize mathematical concepts for educational purposes. He presents a process of composing “dynamic PDF training documents”. The author points out the problem of data converting to needed 3D format, especially when commercial software is unavailable on the computer.

One the main disadvantages of 3D PDF is that modern browsers don't natively implement 3D visualization of models embedded in PDF. To see and interact with them the user must additionally install a special program or plugin for browsers, which creates complexities, including additional periodic updates. May be it is the reason for limited popularity of such approach. That's why online publishers find ways for viewing 3D data in PDF or other formats.

SWF files also provide rich choice of different multimedia elements, including 3D. This technology has been supported by browsers for many years. Unfortunately it is discontinued starting from 12 January 2021 and not recommended for a further usage in favor of HTML5 and JavaScript programming languages.

Some online publishers of academic articles provide ability to submit paper with embedded video or 3D models in U3D format. This is great step in the direction of innovative presentation of articles.

#### **Formulation of the study purpose**

Today hardware and software is developed enough and spread of smartphones, tablets and e-readers leads to easy reaching of users by new multimedia technologies. So the work is devoted to description of data visualization in scientific e-articles using computer to achieve a richer user experience than just reading e-article with text and static illustrations.

#### **Presenting main material**

The object-oriented paradigm (OOP) simplifies programming of a complex component for data visualization. To replace a static figure in e-article it is proposed a component named “viewport” (Fig. 1), which is similar in functionality to built-in “video” element of HTML5. Both can play content but the former allows reader to control point of view and other parameters of model. It consists of four subcomponents intended to meet the following functional requirements:

- showing a static figure or poster in e-article;
- starting and pausing playback by clicking or tapping on a button;

- playing a supplemental audio if any. Audio volume is changed by a vertical slider and can be muted;
- searching for a specific time by dragging a slider on a timeline. An initial slider position can be nonzero and set ahead by author of e-article;
- configuring speed of playback and color mode of background.

The canvas is the built-in element, which occupies a whole space of the mentioned viewport and supports rendering 2D or 3D content. The audio is built-in element and it's needed to listen optional comments for a figure. Audio is synchronized with the playback. There is a toggle button for an interruption and continuation of the playback as well as the slider to seek for an interesting moment. Also the options button gives control over playback rate and background color.

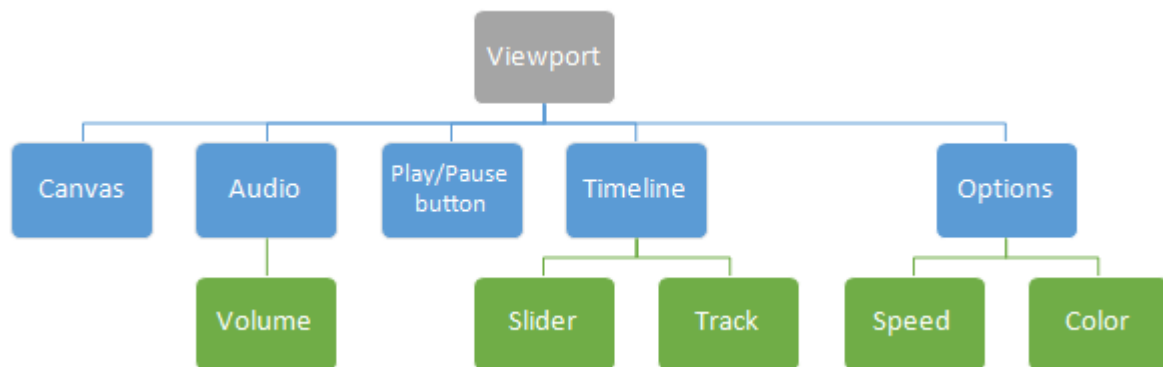


Fig. 1. Proposed UI component structure for data presentation

Content for the playback is stored as collection of snapshots (Fig. 2). The collection can be optimized to reduce its size if the standard zip-compression is not enough. To start playback it is necessary to download only a small part of the collection, so for purpose of saving Internet bandwidth the component requests limited number of snapshots at once. It is analogous to the method a web server uses for a video content.

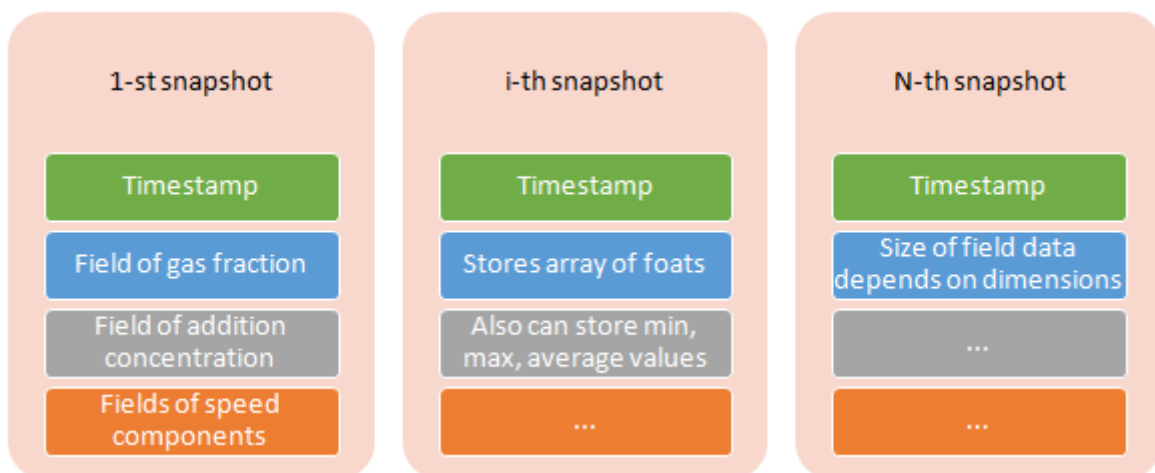


Fig. 2. The sample data snapshot collection of fields relative to mathematical model of metallurgical process

Also OOP helps in rendering set of triangles, which can share properties and logically represent a single 3D model. Thus all data needed to complete rendering are kept in corresponding objects, which are organized into a virtual scene (Fig. 3). Every object has attributes, for example, transformation and can be composed by other objects:

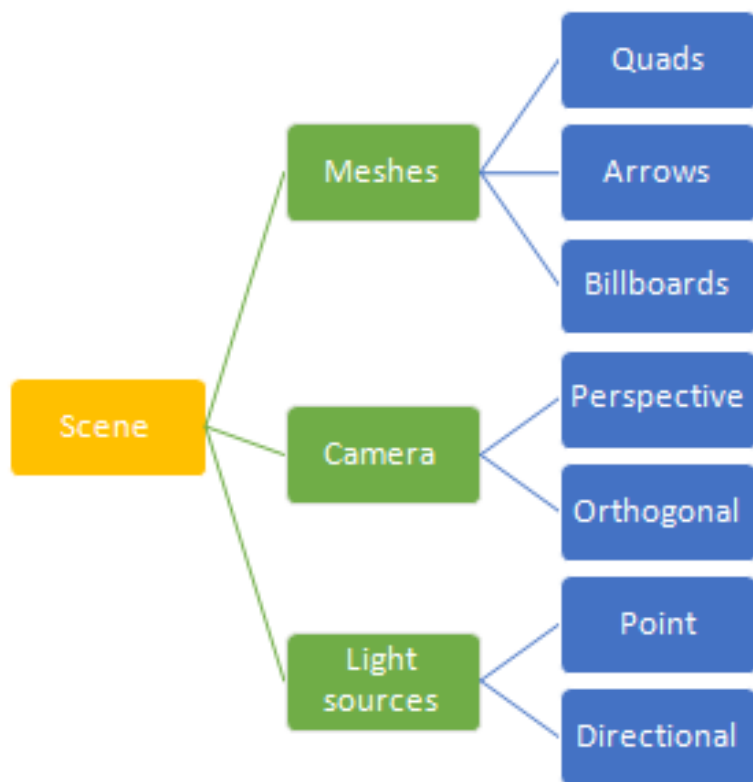


Fig. 3. The virtual scene structure for 3D rendering

- a quad has orientation, position and consists of two triangles with shared normal and color to represent scalar. A triangle has three points, which is used to determine the normal;
- an arrow has color, angle and position consists of two connected lines, defined by three points, which show direction and magnitude of a local vector;
- billboards are used to make text labels, which are always oriented towards camera. These labels with numbers are shown on the coordinate axes and above the quad under the pointer to show related scalar. Ray intersection is used to determine which quad is hovered. The efficient Moller-Trumbore's algorithm calculates distance to intersection point;
- a camera has position, up unit vector and look-at unit vector.

A perspective camera also has field of view. Orthogonal camera is helpful when one needs to see the scene from the top, side or other point of view without perspective transformation;

- a light source has color, intensity, position, direction unit vector or distance (for point light). While two directional lights is enough to view the scene from different points of view the point light source allows to additionally illuminate specific parts.

Above position attributes are points with three floats — coordinates in space relative to reference frame. For orientation change it is used a versor — unit quaternion, because of its lock-free behavior.

Visualization of calculated scalar field and accompanying 3D content is done in few stages. The first stage is preparation of meshes, including import of static 3D models, generating quads and arrows. This stage is executed once and can be time-consuming, so loading notification can be used for reader to wait.

The second stage is updating time, color of quads, vector length and orientation, visibility of objects according to the selected plane of cross-section made along coordinate axis. This stage is started when it is needed to render new frame. The hue-saturation-lightness color space is used get a color for each scalar  $s$ . There is function, which returns a dark blue for the minimum value and a red — for the maximum:

$$c = HSL\left(\frac{2}{3}\left(1 - \frac{s - s_{\min}}{s_{\max} - s_{\min}}\right); 1; 0,5\right), \quad (1)$$

where  $c$  — color,  $s$  — considered scalar from field,  $s_{\min}$  — minimal scalar,  $s_{\max}$  — maximal scalar. On the plane two metric components of speed are needed to calculate an angle  $\theta$  and a length  $l$  of a local arrow:

$$\theta = \arctan\left(\frac{u}{w}\right), \quad (2)$$

$$l = \sqrt{u \cdot u + w \cdot w}, \quad (3)$$

where  $u$  and  $w$  — components of speed got from appropriate fields of snapshot. Length  $l$  is multiplied by some number to regulate appearance.

On the second stage optimization can be made for automatic playback. If the selected speed multiplier of the playback leads to a very fast (for example over 60 data frames per second) change of data in the viewport then more snapshots can be skipped to save resources. From the other side, if the speed is lower than the rate of snapshots in calculated data then a simple interpolation between two snapshots is turned on. This improves smoothness of playback.

The third stage is projection of meshes on the plane of a virtual camera and then rasterization. This stage is perfectly done by any graphical processing unit (GPU).

After the first user-initiated activation of the viewport arrows and quads are created based on the coordinate system and geometry, which were used for calculation of a typical mathematical model. Only color of quads as well as length and direction of arrows are updating during automatic playback or dragging of slider on the timeline. The 2D graphics has some advantage over 3D, because it is simpler and always accessible from the canvas. In the case of a short animation a fully-featured canvas component is unnecessary and can be replaced by GIF-animation in image component.

To reach a broader audience the component should fulfill the following technical requirements:

- support of three or more popular internet browsers;
- support of free media formats;
- running of JavaScript code must be enabled in a browser to bring interactivity and to render 2D graphics or 3D models on the canvas component. Also it is used to attach listeners for pointer events.

**Results.** To test proposed technique an article devoted to a 3D mathematical model of complex metallurgical operation (ladle treatment of molten steel) is chosen. The static figures are replaced by interactive viewports for 3D rendering and manipulation. A ladle is represented by a cylinder mesh. A cross section of scalar fields (gas and addition) is drawn by colored quads. Arrows, rendered by lines, represent vectors of speed field. To render the content there are many free libraries today, which also simplify managing of hierarchical 3D data. An evolution of mentioned fields can be seen using the time slider.

The fig. 4 shows working example of viewport made using proposed approach. At the bottom of the fig. 4 the controls can be hidden when pointer is not above them. A red line is x-axis, which coincides with the radial axis; a green line is the y-axis; a dark blue line is the z-axis.

### Conclusions

Topicality of the research is grounded on a natural inability of regular papers with static information to represent peculiarities of dynamical multidimensional processes considered by scientists in their papers. In addition the level of today technologies development creates good basis to enrich reader's experience by interactive viewports replacing static figures. The proposed technique can be used to implement web components, which allow reader to orbit around a 3D model to see all the details of the system state and analyze process evolution, which cannot be done with a video or an animation and, of course, a static figure. Playing audio expands user accessibility for those who poorly see or want to listen comments. Mentioned advantages greatly improve usefulness of e-article even though a relatively more time is needed to prepare data for the interactive representation. Also two components can be time-synchronized for comparison of data representations in evolution.

If to compare the proposed viewport component with the built-in audio/video component of HTML5, one can see additional selector of playback speed and background color. The viewport has controls, which fulfill requirements listed above and it can be used directly with some styling, for example, transparent background.

The viewport can of course also be used for a presentation of experiment results obtained in laboratory or industrial conditions without excessive simplification or processing of taken records in the case of regular static illustrations.

A further investigation is planned to make the viewport simpler to use and embed to a wide number of papers. It needs to be less time-consuming to prepare 3D data, for example by letting authors to choose ready-to-use models and parameters of typical processes. Proposed approach can be further extended for other branches and specialties not limiting to the metallurgy.

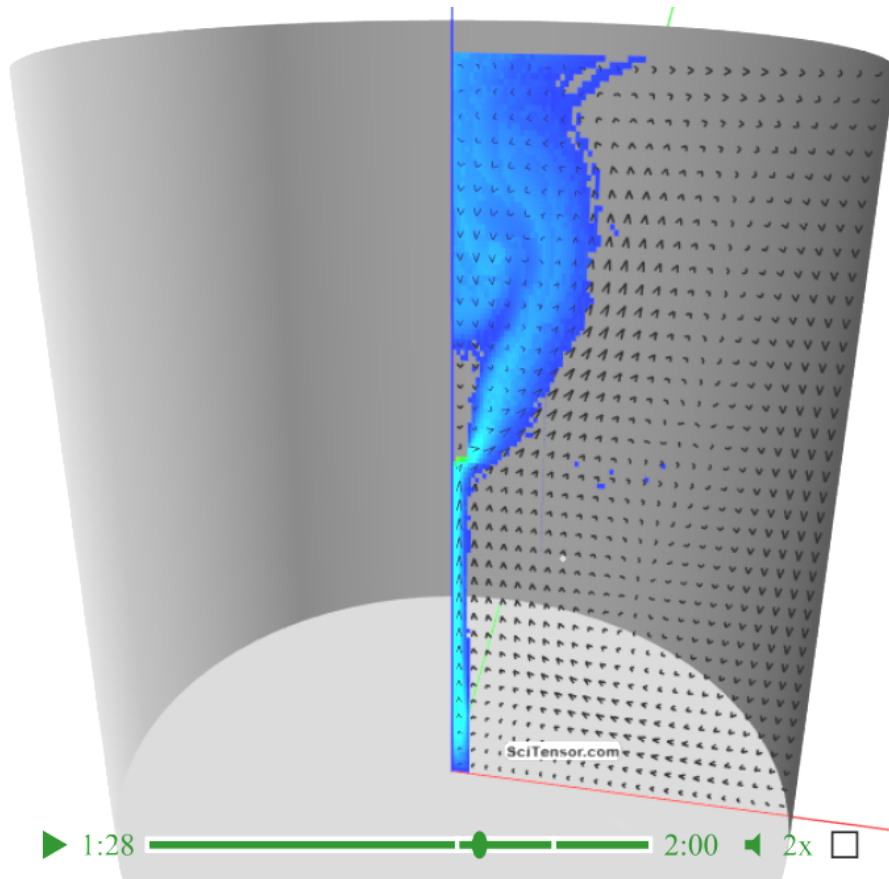


Fig. 4. The viewport renders 3D scene with cylinder and different fields involved in process

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## ВІЗУАЛІЗАЦІЯ РЕЗУЛЬТАТІВ ДОСЛІДІВ У НАУКОВИХ Е-СТАТТЯХ

Красніков К.С.

### Реферат

Комп'ютери дають нові можливості представляти дані, розраховані за допомогою математичних моделей. Простий статичний рисунок не може відображати всі деталі 3D-моделі та еволюції складного фізичного процесу, що може значно обмежити поширення наукових результатів та корисність електронної статті. У цій роботі розглядається представлення даних для читачів мультимедійними веб-компонентами, що замінюють статичні рисунки в електронній статті. Область перегляду складається з вбудованих компонентів популярних Інтернет-браузерів, відповідає представленим функціональним та технічним вимогам, включаючи підтримку безкоштовних медіа-форматів. Показується та пояснюється його структура інтерфейсу користувача, подібна до відеокomпонента. Вміст, який відтворюється областю перегляду, організований за моментальними знімками, які містять масиви чисел та інших даних. Ці знімки використовуються для оновлення віртуальної 3D-сцени. Сцена складається з камери, джерел світла, статичних та генерованих моделей, включаючи кольорові чотирикутники та стрілки для поля швидкості. Як результат, представлена ілюстрація демонструє реалізовану область перегляду із прорисованим станом металургійного процесу в конкретний момент часу. Порівняно з існуючими роботами розглядається надання аудіо-коментарів для області перегляду в електронній статті, що розширює коло його потенційних читачів. Запропонований компонент може відтворювати еволюцію 3D полів, інтуїтивно керуючи відтворенням, включаючи розташування віртуальної камери.

Якщо порівняти запропонований компонент області перегляду із вбудованим аудіо-відео компонентом HTML5, можна побачити додатковий селектор швидкості відтворення та кольору фону. У вікні перегляду є елементи управління, які відповідають функціональним вимогам, і його можна стилізувати за допомогою CSS, наприклад, зробити фон прозорим.

Подальше дослідження планується для спрощення використання області огляду та вбудовування у наукові роботи. На підготовку тривимірних даних потрібно витратити менше часу, наприклад, дозволяючи авторам вибирати готові до використання моделі та параметри типових процесів. Запропонований підхід може бути продовжений для інших галузей та спеціальностей, не обмежуючись металургією.

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