The Next Generation Volumetric Computer Animation System

Abstract

Computer animation systems are used in various industries such as animation movie production, VFX, computer games, product design and advertising. The world market of animation systems is dominated by such systems as Maya, Softimage/XSI, 3D Studio Max (all owned by Autodesk) and Houdini (Side Effects Software) and by specialist systems such as Massive (Massive Software). All these systems were developed in Canada, USA and New Zealand. Europe currently is not developing any production-ready animation systems. Moreover, the main production companies such as Pixar, Industrial Light & Magic, Sony Pictures Imageworks, DreamWorks, Blue Sky Studios and others develop their own proprietary supplemental software tools that are not available on the market.

The objective of this project is to research and develop the core components of an innovative computer modelling and animation system that uses hybrid volume modelling at its foundation. Hybrid volume modelling involves a combination of boundary representations (polygonal meshes and parametric surfaces) with function representations, and exploits their complementary advantages in various application areas.

The proposed system will be based on a number of novel concepts allowing us to overcome the limitations of currently available commercial systems and thus potentially becoming a landmark system of the next generation. This will have far reaching implications both for animation and computer games software tool development and production in Europe.

We intend to research, design and implement a prototype for this new kind of animation system, the core subsystems of which can also be used in game engine development and for the purposes of scientific simulation and visualisation. Such a system will be based on a novel hybrid volumetric representation that is capable of defining both the boundary and internal volume of objects, thus allowing us to deal with soft, hard and malleable objects in a unified way. As part of the research and development stage of this project we will develop a proof-of-concept prototype of such a system and have it evaluated by VFX and computer games production companies, as well as CAD companies.

Section 1: Scientific and/or technical quality, relevant to the topics addressed by the call

1.1 Targeted breakthrough and its relevance towards a long-term vision

Describe the breakthrough(s) that you are targeting to achieve.

Digital creative technologies such as computer animation, VFX and computer games are heavily dependent on the modelling, physically inspired or directable simulation and rendering of time-varying geometric objects. These areas of research are currently entirely stagnant due to the restrictions placed on the types of objects that they can operate on. This is mainly due to the simplistic and outdated view of real world objects where their geometry is represented as a collection of external surfaces. This view of an object is reflected in the currently standard underlying model of its geometry, which consists of a set of surface sheets stitched together to envelope the uniform and homogeneous structure of its material. Such a representation was reasonable and indeed necessary in order to be able to perform object modelling with computers thirty or forty years ago. Modern multiprocessor computers are now able to deal with much more complex data structures and mathematical models, which were previously unimaginable. Thus we believe that it is high time to develop the mathematical and algorithmic underpinnings that in turn will allow us to create a new set modelling and animation tools. Such tools will be able to support the modelling and animation of objects with complex internal structures and microstructures, and of objects composed of diverse materials and possessing diverse densities and other physical properties reflecting their heterogeneous volumetric nature. Another factor of paramount importance is that in computer animation, VFX and games we deal with objects that are not static, but with objects whose geometry and physical properties may change over time.

The breakthrough we are trying to bring about with this project is to introduce the new

paradigm of volumetric computer-aided modelling and rendering for time-variant heterogeneous objects. We can only achieve this by first researching and developing the mathematical and algorithmic foundations and using these to develop novel prototype software tools incarnating this paradigm.

What is the long-term vision (scientific, technological, societal, other) that motivates this breakthrough?

Man-made objects in general are much simpler than objects found in nature. With the rapidly increasing available computer power it is becoming possible to model and render objects, which are much closer to natural objects in their complexity. From the scientific point of view this requires solving a raft of new mathematical and algorithmic problems. New mathematical methods and computer technologies need to be developed in order to handle multi-material heterogeneous objects of the sort of complexity found in nature. With the introduction of such technologies, computer animation and VFX can be made to appear more complex and natural, and computer games can be developed to provide much more believable user experiences. Other areas such as computer-aided design would also benefit from this development as users will be able to manipulate both the external appearance and the internal structures of time-variant objects in ways which are currently not possible.

In general, our long-term vision is that computer modelling will become a tool that can be used to gain a deeper understanding of the natural world and a tool to allow the creation of artefacts of the sort of complexity found in nature.

Explain how this breakthrough is an essential step towards the achievement of your long-term vision, in particular in terms of new forms and uses of information and information technologies.

The breakthrough proposed in this project is an essential step as it will form the basis for further developments towards our long-term vision. The sort of mathematical methods, algorithms and software tools, which we intend to develop and implement, will facilitate the creation of a consortium of industrial and academic partners working together in the application of the proposed models and tools in various areas of computer animation, VFX and games.

Describe the concrete objectives that you would consider to constitute the proof-of-concept of such a breakthrough. The objectives should be those that you consider achievable within the project, in spite of the inherent risks.

The project objectives that we intend to achieve are as follows:

- A formal description of the mathematical model for time-variant heterogeneous objects.
- The development of the set of fundamental algorithms and data structures that would allow us to describe and manipulate such objects.
- The specification of a core system for the modelling, rendering and analysis of time-variant heterogeneous volumetric objects.
- The development of a proof-of-concept system prototype.

- The development of a set of application case studies for computer animation and games.

1.2 Novelty and foundational character

What is the novelty of your proposal?

The novelty of this proposal is evident in the scope and extent of our objectives that are detailed above. These necessitate the development of a new mathematical model and accompanying algorithms and data structures. The modelling of time-variant heterogeneous volumetric objects is not currently supported in any of the existing computer animation or computer game development systems. Therefore, the proposed system specification and its prototype implementation will be completely novel and will be supplemented by a set of case studies that will allow us to test the validity and efficacy of this new modelling paradigm and of this prototype modelling system.

In what way do you challenge current thinking or assumptions? Novelty should come from new ideas, not from the incremental refinement of existing approaches. It can also come from new and unexpected combinations of insights from various disciplines.

Current thinking in geometric modelling is predominantly restricted to describing the surfaces of objects without regard for the internal structure and properties of volumetric objects. Both our goal and our approach to the geometric modelling of time-variant objects challenge this status quo. Our goal is to be able to represent an object in its full complexity or at least as close to it as it is possible. We wish to be able to represent an object using macro, meso, micro and nano levels of detail if required by a particular application, such as scientific visualisation for instance. The approach that we propose will use continuous real vector-functions of point coordinates instead of the currently prevalent polygonal meshes and parametric surfaces. Using existing advanced mathematical methods, such as the theories of R-functions and of the topological CW-complexes, real vector-function models and existing surface models can be combined into a hybrid model to support a very wide spectrum of application requirements.

What is the scientific foundation that you aim to develop?

We aim to develop a scientific foundation for the modelling and rendering of time-variant heterogeneous volumetric objects, which will require the development of new mathematical models, algorithms and data structures for its implementation. Subsequently we will develop an original design for a new type of volumetric computer animation system as well as appropriate user languages and interfaces.

1.3 S/T methodology

Provide an outline of the scientific and technological approach or methodology by which you will attempt to reach your objectives.

Bellow we present a Work Breakdown Matrix that outlines all the deliverables and all the tasks that need to be completed in order to achieve the objectives of the proposed project.

Work Breakdown Matrix

Completion by Month	6	12	18	24	30	36	40
	Mathematical Development **WP1**	Algorithm Development **WP2**	Language Description Specification **WP3**	System Component Architecture **WP4**	Component Prototype implementation **WP5**	Animation System Prototype Implementation **WP6**	Animation System Prototype Evaluation **WP8**
Geometric & Volumetric Modelling	P1 & P4 **WP1.1**	P1 & P4 & (P2) & (P5) **WP2.1**	P1 & P3 & (P2) **WP3.1**	P1 & P2 **WP4.1**	P1 & P2 **WP5.1**	P1 & P2 & (P8) **WP6**	
Animation & Simulation	P1 & (P4) **WP1.2**	P1 & (P5) **WP2.2**	P1 & P3 **WP3.2**	P1 **WP4.2**	P1 **WP5.2**		
Surface & Volume Rendering	P8 & (P1) **WP1.3**	P8 & (P1) & (P2) **WP2.3**	P1 & (P8) **WP3.3**	P1 & (P2) **WP4.3**	P8 & P1 & (P2) **WP5.3**		
User Consultation **WP7**	P6 & P7 & (All) **WP7.1**		P6 & P7 & (P1) **WP7.2**			P6 & P7 & P5 & (P1) & (P2) & (P8) **WP7.3**	
End User Testing **WP8**						P6 & P7 & P5 & (P2) **WP8**	

Detailed definition of the Work Packages

WP 1. Mathematical development

WP 1.1 Revision and extension of the mathematical basis of hybrid modelling in the form of Implicit Complexes (IC).

WP 1.2 Revision and extension of the mathematical basis of time-varying ICs, events. Topological analysis of time-varying volume objects.

WP 1.3 Mathematical development of hybrid surface/volume rendering for ICs including special topics such as subsurface scattering and other volumetric effects.

WP 2 Algorithm development

WP 2.1 Algorithms development for creation and transformation of volumetric objects using primitives, operations and relations. Analysis algorithms of objects' topological and metric properties.

WP 2.2 Algorithms development for creation of time-variant objects and analysis of their temporal properties.

WP 2.3 Algorithms development for hybrid rendering of volumetric objects involving GPUs (Graphic Processing Units).

WP 3 Language specification

WP 3.1 Specification of high-level language for creation and transformation of volumetric objects including their dependencies

WP 3.2 Specification of high-level language for defining time-variant objects including events and coordination temporal dependencies.

WP 3.3 Specification of language for rendering selected scenes and animation sequences.

WP 4 System component architecture

WP 4.1 Designing the modelling sub-system architecture

WP 4.2 Designing the animation and simulation sub-system architecture

WP 4.3 Designing the surface/volume hybrid rendering sub-system architecture

WP 5 Component prototype implementation

WP 5.1 Implementation and testing the modelling sub-system components

WP 5.2 Implementation and testing the animation and simulation sub-system components

WP 5.3 Implementation and testing the rendering sub-system components

WP 6 Animation system prototype implementation

Combining the implemented components into the entire system and basic testing.

WP 7 User consultation

WP 7.1 User consultations on requirements to modelling and animation system capabilities from different applications points of view: animation, game development, CAD and scientific visualization

WP 7.2 User consultations on requirements to high-level languages and various sub-system components

WP 7.3 User consultations on requirements to the overall system architecture

WP 8 End user testing

Testing the system prototype in a VFX and computer games production environment, in scientific visualization and CAD case studies.

Provide evidence that you are aware of the level and nature of the risks of failure, and that you have a good idea on how to address these risks.

[TO DO]