Physically-based modelling techniques

Nicolas Castagné

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Nicolas Castagne [ACROE&INPG]

Contributors: Matthieu Evrard [ACROE&INPG]

Overview

Physically-based modelling have developed considerably for the past 20 years in computer graphics, computer music, haptics and virtual realities [→ Physically-based modelling].

For many, the practice of computer physically-based modelling is necessarily based on a numerical analysis process. Such a traditional methodology consists in first constructing a continuous-time series of equations using the laws of physics, and second using some numerical analysis technique in order to digitalize these equations to compute them. The digital model is then only seen as an approximation of the first, which is presented as ideal. A recurrent aim is to evaluate and minimize the divergence or numerical bias. Many such one-shot physically based models of a specific object or phenomenon are obtained through such a methodology (examples: fluid effects, smoke, water; acoustic strings; etc.).

Though this one-shot model methodology is still quite common, it would not be sufficient to have a specific physically-based algorithm for every category of phenomena to be generated in the contexts of animation, sound synthesis, movement synthesis, virtual realities, etc. More generic methodologies are needed.

Hence, as opposed to one-shot models of a specific phenomenon or object, a major research direction in physically-based modelling deal with the design of generic physically-based techniques and methodologies that allow the building of a model for various categories of phenomena and objects. As well as a number of signal-based synthesis schemes have been proposed over years, various physically-based techniques have been introduced, each one allowing the design of models for various categories of objects and phenomena.

Problematics

The problematic of physically-based techniques can be analysed through optimality, quality, genericity, and usability [Castagne et al., 03].

- Optimality

An optimal technique should allow a minimal computing coast, i.e. be efficient enough to allow huge models to be computed in real time.

- Quality

An optimal technique should permit the design of high quality models, i.e. allow expressing models that generate phenomena as convincing, vivid, believable as wanted [→ Believability_ 1&2].

- Genericity

An optimal technique should maximize the richness and diversity of the obtainable phenomena, so that a large panel of physical behaviours may be obtained by using it. Additionally, as an important point, the technique should not be restricted to a single sensoriality, but allow the design of models that can be at the same time heard, seen and manipulated. This goal is particularly difficult to reach, since the awaited phenomena, and the corresponding physical properties of object, may differ radically. It is also particularly important, in order to obtain multisensory virtual objects based on physical modelling [→ Physically-based modelling techniques for multisensory simulation].

- Usability

Research aims no only at developing models and techniques, but also at developing physically-based modelling know-how in the end user communities. A physically-based

modelling technique usually comes along with a specific approach to the modelling process. It provides – and imposes - a support and a guide for the modelling activity itself, and often consists more or less in a modelling language. Hence, the search of a usable technique is a major goal: an optimal technique should be usable enough to be implemented by end users (eg: a musician, or an animator, etc.), and to be learnable in a reasonable manner.

Usability first calls for intuitive parameters, and more generally for the possibility of an efficient mental model regarding the technique. It also implies, importantly, that the technique should be robust against the modelling process: it should guaranty some quality in the obtained behaviours, whatever the model is, and however it was build, as long as it relies on the technique. Finally, [Castagne et al., 03] assumes that usability strongly relates with modularity: an optimal technique should hence be modular, allowing the building of a model by assembling elementary building blocks.

Categories

Physically-based modelling techniques developed in parallel in computer graphics, computer music, virtual realities, haptics, etc. Most techniques are dedicated to a category of model depending on the synthesized phenomena. Hence, one can distinguish upon [→ Physically-based modelling techniques for movement synthesis and animation] and [→ Physically-based modelling techniques for sound synthesis].

Finally, a few techniques, though, are usable in all the previous cases, but may also apply the important case of multisensory simulation.

References

[Castagne et al., 03] Castagne N, Cadoz C: "10 criteria for evaluating physical modelling schemes for music creation", proc. of the Digital Audio Effects Conf., London, 2003.

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Believability_ 1&2

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