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Physically-based modelling

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Physically-based modelling originates in the 70's. Since the 90's most of the research regarding modelling in virtual realities, animation, sound synthesis, movement synthesis, haptics, etc, in which models are employed to produce sensible phenomena, deal with physically-based modelling.

Physically-based modelling as opposed to signal based modelling

A model can be said to be physically-based when the modelling and the synthesis of sensible phenomena one want to produce (a sound, a movement, etc) by using signal-based models, is replaced with the modelling and the simulation of its physical origin or cause (the sound structure that produces the sound, the objects that moves, some prominent properties of a real-world object, etc.) [Borin et al., 94] [Cadoz 94]. Hence, physically-based modelling corresponds with an historical evolution of the categories of models. According to the literature, the evolution from signal-based to physically-based models is guided:

- By the interest of the physically-based parameters as compared to the signal based parameters (e.g. modifying an inertia in a string-like model produces a more consistent effect on perception than modifying, for example, the frequency of an oscillator in an additive synthesis patch).
- By the aim of obtaining more believable synthesized phenomena and interactive virtual scenes. Modelling and simulating the cause (instead of the phenomena themselves) allows obtaining a wider range of validity for the model.

Physically-based modelling as opposed to physical modelling

As a common property, physically-based models implement some laws of physics more or less freely. However, one should distinguish upon physically-based modelling (as practiced in virtual reality, etc.) and physical modelling (as practiced in physics, acoustics, etc.). The two differ in their goals, problematic and tools [Castagne et al., 04].

Physical modelling is rooted on the search of a better understanding of real world objects. Models tend to become more and more complex (in the sense that more and more behaviours are considered for a given object) and precise (in the sense that the bias between the generated behaviours and the behaviours of the real object is made the smallest possible). The research also aims at obtaining accurate models for prediction, i.e. models that can be used to foresee the behaviour of a hypothetical object one have in mind. In this context, traditional physics (with continuous time and space) is a key tool. A computable algorithm is eventually obtained by implementing a numerical analysis process on the model. Simulation (genrally non-interactive) is used in order to study the validity of a model, by comparing the model's outputs with measurements on the real object.

As an example, acoustics produces more and more complex models of the bow-string interaction, enabling a better understanding of the laws at hand, and cosmology produces more and more accurate models of the universe. Also, one would build a physical model of a bridge while designing it to study its resistance to constraints like weights, air, etc.

The goals pursued with physically-based modelling (as practiced in virtual realities, etc.) differ. One aim at finding the appropriate physical rules, and reusable, generic and modular algorithms that could improve the quality of the generated sensible phenomena, and of the interaction of the user with the

model when it is computed, through gesture transducers, force feedback transducers, etc. Physically-based algorithms are implemented within the model with the aim of guarantying that the model is lively and believable, even when the model do not refer to a real object [→ Believability_ 1&2].

The study of a real object is never an aim *per-se* in physically-based modelling but, when needed, a tool for further research. A physically-based model may have no real counterpart (eg. be non-realistic) but still be considered as perfectly valid. Models are evaluated mainly through subjective judgments. Rather than the quality of the model as compared to a real object, one will seek the quality of the model's behaviour as for the user, when heard, seen and manipulated. Precision in modelling is not the goal, and the implementations of physical laws are made freely, as long as the model behaviour keeps being satisfying. Research necessarily deals at the same time with technical aspects (physically based frameworks, devices for interacting with the models, appropriate user interfaces, etc.) and psychological or at least psychophysical concerns.

Finally, as evidence, the frontier that separates physical modelling and physically-based modelling is not that clear. Mutual empowerment is possible, and needed (eg: physical models often led to convincing models to be used in virtual realities, computer graphics and computer music). But researchers on physical modelling and on physically-based modelling respectively point goals, needs, and results that are different. See also [→ Physically-based modelling techniques].

References

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[Castagne et al., 04] Castagné N, Cadoz C: Physically-Based Modeling and Music vs Physical Modeling and Acoustics – proceedings of the 18th International Congress on Acoustics – ICA'04 – Kyoto, Japon, 2004.

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