Fidelity Metrics for Animation

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ABSTRACT

In this paper, the problem of evaluating the fidelity of animations will be addressed. Plausible simulation and the perceptual impact of animations generated using approximations or interactive manipulation will be discussed. We will examine some recent work in the development of perceptual metrics for evaluating the visual fidelity of animations. This includes investigations into the perception of collisions and, more recently, psychophysical experiments that examined human sensitivity to dynamic anomalies, leading to the first steps to developing a metric to evaluate the visual fidelity of physically-based animations. In addition, we describe several new experiments and provide some new results regarding the role of task in the perception of anomalous collision events.

Keywords
Animation, perceptually adaptive graphics, fidelity metrics, collision handling, psychophysics.

1. INTRODUCTION

In recent times, researchers and practitioners in Computer Graphics have become increasingly aware of the need for objective, quantitative metrics to evaluate the realism of their images, animations and virtual environments. In tandem with this realisation, the role of plausible, as opposed to accurate, simulation has also increased in importance. In order to guarantee plausibility, an awareness of the perceptual impact of simplifications and distortions is imperative. In response to this need, some recent research efforts have been directed to the development of metrics based on empirical data, in some cases derived from new psychophysical experimentation.

In this paper, we will first provide a brief overview of recent advances in the development of fidelity metrics in animation, in particular for animation, and the application of perceptual principles in computer graphics. Then, in Section 3, we will discuss in more detail our recent work on the perception of collisions. We will present some results from a new experiment that examined the effect that a distracting task has on people's ability to notice anomalous collisions. Section 4 follows with a discussion of fidelity metrics for animation and Section 5 concludes with some considerations for the future.

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2. BACKGROUND

Fidelity metrics for rendering have been proposed by several researchers e.g., [Dal93, Mys01] and also evaluated [Wat01]. Heuristics for adaptive refinement of geometry based on perceptibility have also been successfully implemented [Fun93, Lue01] and fidelity metrics based on memory have been proposed for Virtual Environments [Man03]. However, only recently has there been a concerted effort to examine issues of perceptibility and plausibility with respect to animations and simulations.

Barzel and Hughes [Bar96] first introduced the concept of plausible simulation, and pondered the meaning of physically plausible vs. visually plausible motion. They suggested that there are situations in which inaccurate or probabilistic techniques implemented in a noisy or textured environment are likely to look more realistic than the physically correct solutions, which have the tendency to appear sterile and repetitive. Building on these ideas, Chenney and Forsyth [Che00] developed a scheme for sampling plausible solutions to constrained physical simulations. They allow a user to provide a function that describes physical plausibility, which is then used to generate a range of animations that satisfy both this user-defined definition of plausibility and any physical constraints to be imposed upon the system. For example, the product of unnormalised Gaussian bell-shaped functions is used to describe the physical plausibility of a bouncing ball animation – each collision normal is thus considered to be normally distributed around the perfect, vertical, direction.

Popovic et al. [Pop00] also allow for the manipulation of physically-based animations by letting an animator play with the physical properties of a simulation until a desired end-result is achieved. In this case, the definition of plausibility is purely under the control of the animator. In our recent work, discussed in the next sections [Osu01, Osu03], we examined these ideas of plausibility more closely with respect to human visual perception and conducted many psychophysical investigations upon which a perceptually based fidelity metric could be based.

Further investigations in other areas of animation have been recently undertaken. For example, Reitsma and Pollard [Rei03] carried out a series of user studies that examined human sensitivity to errors in ballistic motion introduced by motion editing. For further information and an overview of some of the issues introduced in this section, we refer the reader to two recent courses on perceptually based graphics [Fer03] and plausible simulation [Hug03].

3. THE PERCEPTION OF COLLISIONS

In our previous work, we investigated the role of various factors on human perception of anomalous collisions [Osu01]. In real-time animation, if fully-accurate collision detection is performed, this can often lead to long delays if the objects are complex or there are many colliding groups. We found that the effect of such a delay at the moment of impact on the perception of the user was highly detrimental to the perceived realism. To ameliorate this effect, simplified volumes are often used to compute collisions between objects in real-time simulation, but this can also lead to a variety of dynamic anomalies – separation between the objects when they collide, or less accurate physical response. We found that the negative effect of both of these factors was significant, but found that perception could be improved by adding more distracters (other objects moving in the scene), occluding the view or adding a random spin after collision.

It was obvious from these studies that a variety of factors and interacting effects impact upon our ability to perceive anomalous physics. Many further factors could be considered, such as texture, lighting and shadows. The role of attention was examined to a certain extent, in that we examined the role of different types of distracters i.e., visually similar or dissimilar to the colliding entities. However, attention is very much affected by the task a user is undertaking, and this factor was not included in our earlier study. We now present a new set of experiments that examine this effect.

New Experiments: The Role of Task on the Perception of Separation between Colliding Objects

We examined the role of task in predicting when people will detect anomalous collisions. We conducted three experiments to examine the effects of spatial distortions in the presence of varying cognitive loads.

3.1.1 Experiments

Fourteen observers were paid to participate in the experiments: 10 male and 4 female undergraduate students, ranging in age from 19 to 28. All observers had normal or corrected-to-normal vision and all were naïve as to the purpose of the experiments. The display used is shown in Figure 1. Between one and four pairs of colliding spheres, of diameter 2cm, simultaneously approached each other and collided with each other. In the *Nothing* condition, no further distracters were shown - while in the *Visual* and *Active* conditions, a brightly coloured object was displayed in the centre of the screen. The colour and model of this object was randomly chosen for each run, and in the active task, it also changed colour randomly 1 to 6 times while the spheres were moving. A correct collision response, in the absence of friction and gravity, was computed.

We used a 3x4x4x5 factorial design i.e., 3 conditions: *nothing, visual* and *active*; between 1 and 4 visible collisions; 50% of the runs were with no gaps, and 25% with a small or large gap size, so we say there were 4 types of gap condition; and all conditions were repeated 5 times for all subjects. Each event was shown for a fixed number of frames, after which the observer was told to click the left mouse button if they thought that all collisions were correct, or the right button if they perceived a gap when any pair of spheres collided. Either no pairs or one pair only collided after leaving a gap. In the case of the active condition, the observers were told that they now had an additional important task to perform: to count the number of times the distracting object changed colour during that event and to type in that number on the keyboard (we didn't record their answer – this task was present purely for distraction purposes).

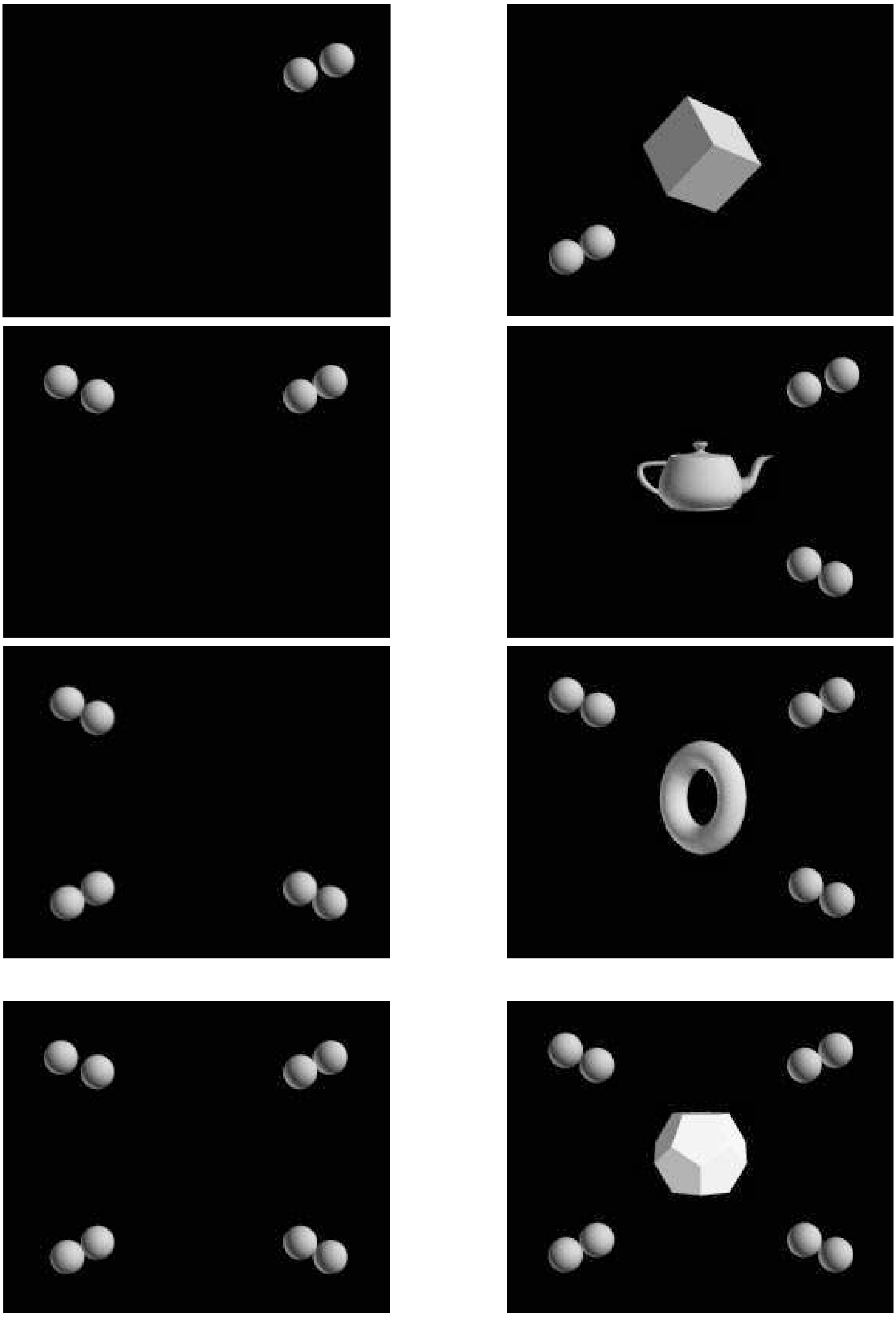

Figure 1: Displays for the experiment to evaluate the effect of attention. The left-hand column shows the *Nothing* condition i.e., no distracting object or task present. The right-hand column shows the display for the *Visual* and *Active* conditions. In the latter case, the central object also changed colour several times.

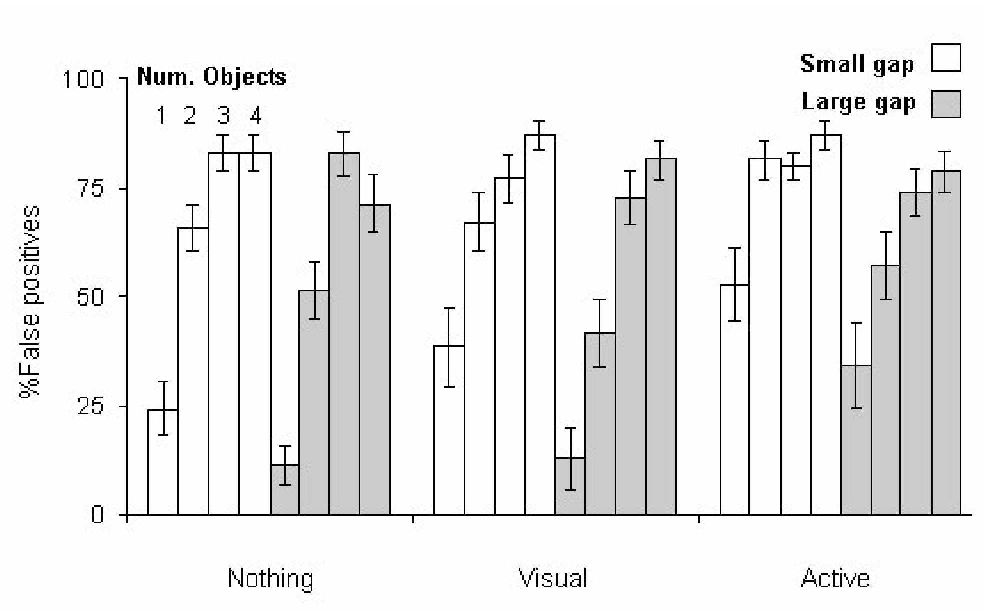

Figure 2: Effects of no task vs. visual and active tasks on the perception of gaps

3.1.2 Results

Figure 2 shows the results for the experiments and single factor ANOVAs were conducted on all results. For each group, the four bars represent the results for 1, 2, 3 and 4 visible pairs of collisions respectively. The number of visible collisions represents the strongest effect for all three conditions ($p < 0.0001$ when collapsed over condition). We found no reliable differences in performance between the visual and nothing conditions for either the big or small gaps (also consistent with previous results that visually dissimilar distracters do not have the same impact as visually similar ones). Significant differences were observed in performance between the nothing and active conditions for 1 and 2 visible collisions with the small gap and for 1 visible collision with the big gap (p = 0.03, 0.01, 0.04 respectively). When comparing the visual with the active condition, marginal results were found only for 2 visible collisions with the small gap and both 1 and 2 visible collisions with the big gap.

3.1.3 Discussion

We have re-affirmed the fact that visually homogeneous distracters have a strongly degrading effect on people's ability to detect gaps between colliding objects. However, the addition of a brightly colored and randomly rotating object did not reduce their performance significantly. We found that the task we gave them i.e., to count the number of colour changes, acted as an additional distracter at the lower levels, but its effect diminished with increasing distracters, indicating that the number of visually homogeneous distracters was the strongest factor in this case. However, we must stress that this scenario is quite artificial, as normally people would not be looking for anomalies while also performing an active task. The real challenge in the future is to design experiments that could assess this in an objective way, passively rather than actively.

4. FIDELITY METRICS

The studies described in [Osu01], and outlined in the previous section, provided some interesting insights into the factors that affect our perception of certain dynamic events. They were not, however, sufficient to provide the basis for an empirical metric, as they were more qualitative than quantitative in nature. Therefore, more recently we ran some psychophysical experiments that allowed thresholds to be found for human sensitivity to dynamic anomalies [Osu03]. These studies were inspired by some earlier psychophysical experiments carried out by Kaiser and Proffitt [Kai87]. We showed participants a range of dynamic events i.e., collisions between spheres, or between a sphere and a more complex object, and applied distortions in a methodical manner in order to find the thresholds at which these distortions became perceptible. Such distortions included linear and angular velocity errors, delays or separation between objects at the moment of impact and erroneous changes to the post-collision trajectories of the objects.

Some interesting biases were found and this information, along with the thresholds measured, was used to define a visual plausibility function. This was similar to that proposed in [Che00], but was now based on psychophysical data and hence took the perception of the viewer into account. For full details of the experiments and the metrics proposed, please refer to O'Sullivan et al [Osu03].

5. CONCLUSIONS AND FUTURE WORK

The areas of plausible simulation and fidelity metrics for animation are exciting new areas for future research. Indeed, the problem of fidelity measurement for image synthesis, virtual environments, behavioural animation, haptics, audio rendering and many other related areas is still a major challenge that we are far from solving. This is not, however, a reason to be discouraged as each small step brings us closer, not only to achieving truly realistic simulations, but also to understanding human perception more clearly. Close ties between researchers from different disciplines, such as psychology, graphics and vision, will be imperative in these future endeavours.

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