Virtual Camera Planning: A Survey

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Abstract. Modelling, animation and rendering has dominated research computer graphics yielding increasingly rich and realistic virtual worlds. The complexity, richness and quality of the virtual worlds are viewed through a single media that is a virtual camera. In order to properly convey information, whether related to the characters in a scene, the aesthetics of the composition or the emotional impact of the lighting, particular attention must be given to how the camera is positioned and moved. This paper presents an overview of automated camera planning techniques. After analyzing the requirements with respect to shot properties, we review the solution techniques and present a broad classification of existing approaches. We identify the principal shortcomings of existing techniques and propose a set of objectives for research into automated camera planning.

1 Introduction

At a very basic level one of the objectives of photography and cinematography is to capture and convey information. Deciding where to position a camera or how to move a camera necessarily raises questions as to what information is to be conveyed and how this will be achieved. We propose three levels of description for the properties of an image: geometric, perceptual and aesthetic. Geometric properties capture the absolute and relative screen position, orientation and sizes of objects. Perceptual properties refer to intermediate stages of the visual processing pipeline, for example, the occurrence of visual gestalts and other properties that impinge on our recognition of objects and their spatial relations with each other. Aesthetic properties relate to notions of shot composition and are typified by terms frequently used (but hard to algorithmically characterize) by artists and art scholars, for example, compositional balance and unity.

In transposing these notions to virtual environments, researchers have been working on approaches to assist and automate positioning and path planning for virtual cameras. A common approach is to invoke declarative techniques by which a user articulates the properties required in the shot (*e.g.* what should be on the screen, where on the screen, which vantage angle) and a solver computes a solution, set of solutions, or best approximation to a solution. To date most actual systems rely solely on geometric properties. This paper presents a survey

A. Butz et al. (Eds.): SG 2005, LNCS 3638, pp. 40–52, 2005.

of virtual camera planning techniques, and we structure our review by refering to two criteria:

1. the expressivity of the set of properties *i.e.* the assumptions pertaining to the properties, the qualitative and quantitative characteristics as well as the range of possible properties;
2. the characteristics of the solving mechanisms (*e.g.* generality, optimisation, local-minima failure, and computational cost).

In Section 2 we present the principles of camera planning and cinematography as they apply to the use of real world cameras. Section 3 reviews the uses of the cameras in computer games, a demanding practical field of application, and in Section 4 we review existing research before concluding with our requirements for future research.

2 Camera Planning and Cinematography

Direct insight into the use of real-world cameras can be found in reports of photography and cinematography practice [1,22,21]. Cinematography encompasses a number of issues in addition to camera placement including shot composition, lighting design and staging (the positioning of actors and scene elements) and an understanding of the requirements of the editor. For fictional film and studio photography camera placement, lighting design and staging are highly interdependent. However, documentary cinematographers and photographers have little or no control of staging and we consider accounts of camera placement in cinematography within this context. Indeed, real-time camera planning in computer graphics applications (*e.g.* computer games) is analogous to documentary cinematography whereby coherent visual presentations of the state and behavior of scene elements must be presented to a viewer without direct modification to the position or orientation of the elements.

2.1 Camera Positioning

Whilst characterizations of cinematography practice demonstrate a degree of consensus as to best practice, there is considerable variation in its articulation. Accounts such as Arijon's [1] systematically classify components of a scene (*e.g.* according to the number of principal actors) and enumerate appropriate camera positions and shot constraints. Not surprisingly, Arijon's procedural description of camera placement has been cited as the motivation for a number of existing automatic camera planning systems. By contrast accounts such as Mascelli's [22] are a less prescriptive and formulate camera planning in terms of broader motivating principles, such as narrative, spatial and temporal continuity.

2.2 Shot Composition

Camera positioning ensures the general spatial arrangement of elements of the scene with respect to the camera, thereby placing a coarse constraint on the