THE ARNOLFINI PORTRAIT IN 3D
CREATING A VIRTUAL WORLD OF A PAINTING WITH INCONSISTENT LINEAR PERSPECTIVE

by Philip Jansen

Abstract In spite of its almost photographic realism, the Arnolfini Portrait by naturalistic painter Jan van Eyck exhibits faulty linear perspective. This paper describes the creation of a three-dimensional virtual reconstruction of the painting’s interior scene using commercial modelling and image processing software. The result presented here is a rendering of the reconstructed scene closely resembling the original painting, and demonstrating what the painting would have looked like if it had had correct linear perspective. The three-dimensional representation of the portrait may be of interest to art historians, and could be employed in a virtual exploration and learning environment.
1 Introduction

The Arnolfi Portrait in Figure 1a is a 1434 painting by the Early Netherlandish painter Jan van Eyck. It depicts wealthy Italian merchant Giovanni di Nicola di Arnolfini and his wife, in what is generally assumed to be a nuptial room in their home in the Flemish city of Bruges. Whilst being a prime example of newfound oil painting techniques, the portrait is also considered a masterpiece of Western Art in terms of originality and complexity. Its expression of space, presence, individuality and psychological depth—the latter through many symbolically charged details—has received high praise.

Readily apparent is the painting’s beautiful lifelike quality, a testament to Van Eyck’s acute sense of minute variations in light and shade, and his way of painting exactly what he observed. On a geometric level, however, this realism is superficial, as the spatial structure of the scene is rather inconsistent. The painting does not adequately follow the rules of linear perspective. The discovery of this artistic method to approximate human vision sparked the development of naturalistic painting at the beginning of the Renaissance, causing a further digression from the stylised figures of medieval art.

The issue of the painting’s perspective raises the question of what the original scene would have looked like. In pursuit of an answer, this article describes the process of creating a full three-dimensional virtual reconstruction of the interior space depicted in the Arnolfi Portrait using traditional computer aided design (CAD) tools, and generating a version of the painting with correct perspective by means of this reconstruction.

2 Linear perspective in the Renaissance

Linear perspective is a mapping of the three-dimensional world to a plane—which could be the canvas of a painter, or a computer screen. An image of each visible point in the real world is created by drawing from it a line to the centre of projection—the eye of
the painter, or vantage point—and marking this line’s intersection with the plane. Florentine architect Filippo Brunelleschi (1377–1446) is credited with inventing linear perspective in about 1415—nearly two decades before Van Eyck made his painting.

What characterizes linear perspective is that images of three-dimensional parallel lines converge to a single point, called a vanishing point. The images of lines parallel to the canvas or image plane, however, do not meet in a real point, but in infinity, and thus remain parallel. Often there are three major, perpendicular directions in a scene, and painters frequently set their canvas parallel to two of them. Hence they need only construct one vanishing point for the third direction, that is, for the orthogonals. The Arnolfini Portrait is one such painting and should, but does not, adhere to one-point linear perspective. This concept is illustrated in Figure 1b.

Van Eyck’s painting lacks a steady structure for converging lines, as it holds over a dozen individual vanishing points, scattered around the central region of the canvas—many of which involve minor details. It seems to maintain geometric consistency only at a local level.

3 Related work

Van Eyck’s pictorial constructions have been the subject of scholarly exchanges ever since the beginning of the last century. Distinguished art historian Erwin Panofsky, well-known for his iconological interpretation of the hidden symbolism of the portrait, was the first to raise interest in its spatial geometry (1934). Since then, there have been many theories on the topic of its perspective—demonstrating that the painting can uphold the illusion of special geometric coherence.

Antonio Criminisi, Martin Kemp, and Andrew Zisserman (2002) explored the merits of computer vision techniques in the virtual reconstruction of old paintings for perspective analysis. They used algorithms, devised by Criminisi (2001), for the automated process of creating faithful, interactive three-dimensional representations straight from the surface of a painting, dealing with pattern completion to fill in hidden areas, and allowing for new views of a scene to be generated. Judicious application of their reconstruction techniques requires a painting to be of sound perspective, i.e. adhere well to the rules of linear perspective.

Criminisi, Kemp, and Sing Bing Kang (2004) investigated the optical properties of the centrally located convex mirror. Assuming that the mirror has perfect spherical curvature (as it was most likely cut from a glass blown sphere), they proposed algorithms for rectification of the distorted image in the mirror, mathematically warping it to normal projection, and consequently gaining a clear view of the scene from the other side of the room. In their assessment of the rectified version of the mirror image, they concluded that Van Eyck’s original rendering had some minor faults (if realism was intended). They corrected these manually in the transformed image.

4 Virtualising the painting

The novel algorithmic methods to ‘virtualise’ a painting offer great advantages over traditional CAD tools. However, they require paintings to strictly obey the rules of linear perspective.

The Arnolfini Portrait misses this requirement by a considerable margin. Using Canny edge detection, Criminisi et al. (2002) accurately computed a few of the painting’s main vanishing points. These have been reproduced and extended by the author in Figure 1c, and convincingly show the painting to be ‘consistently inconsistent’ as regards its global geometry. Hence the author was forced to reconstruct the original scene by hand using commercial three-dimensional modelling and image-editing software.

4.1 Building a perspective framework

Even with this approach, a final reconstruction will still have to feature linear perspective. Therefore, guidance was needed in how to properly interpret the painting’s faulty spatial geometry: its existing groundwork had to be translated into one that is of sound perspective, with minimal overall geometric alteration. After careful analysis, the author decided to have the orthogonals converge at the vanishing point of the floorboards, which, together with the back wall, constitute the painting’s principal geometrically coherent section. Figure 1d shows the resulting perspective framework—and backbone of reconstruction—projected onto the painting.
4.2 Determining the size and position of objects

The manual construction of an accurate model of the scene requires the comparative size and distances of its elements to be known. For convenience, the author computed absolute real-world dimensions, instead of relative ones, and only for key elements; the remainder was established directly within the modelling program used (as explained later on).

The absence of any clear structure with a precisely-known depth, by proportion, made it impossible to uniquely recover the depth of the original scene using perspective geometry. Therefore, all of the measurements are ultimately based on one or more of the following few assumptions.

**Height of the individual in the mirror image.** The rectified convex mirror reflection by Criminisi et al. (2004) in Figure 2 was instrumental in determining the approximate size of most scene structures. In it one can observe a man—thought to be Van Eyck himself—striking a casual pose at the room’s entrance. If this man is assumed to be of average height for a West European male of high social status, in mediaeval times, he may likely have been 1.75 m tall. Then, since the wall beside him is parallel to the image plane—rendering accurate depiction probable—he can reliably serve as a reference object to determining its size. This way the author established the room’s breadth and height at 3.5 m and 2.9 m, respectively. Through these measurements, in turn, size estimates could be made for other two-dimensional elements facing the viewer.

**Breadth of the windows.** Both windows of the room (as seen in the mirror image) seem identical in size. They lend an air of elegance and must have been rather tall and slim. Considering their height expressed in terms of the aforementioned individual’s height, the author reckons them each about 1 m in breadth. This measurement was used as a reference to calculate the depth of other elements in the scene. A subsequent length of approximately 1.8 m for the bed adds to the plausibility of this assumption. Also, judging from the mirror image, the room’s total length is 5 to 6 m.

**A chair behind the bed hangings.** Careful examination of the canvas area just left of the woman reveals that a richly decorated panel against the back wall is in fact part of a chair—below, a small portion of an armrest is visible. Therefore, contrary to what plain observation may lead one to believe, there should be some 0.5 m of space between the bed hangings and the back wall.

**Position of the chandelier.** The brass chandelier is assumed nearly centred on the window with respect to its ‘orthogonal’ position.

4.3 Building the reconstruction model

With the geometrical data obtained, a complete three-dimensional computer model of the painted scene was built. The software used for this purpose was Autodesk 3ds Max 9, a professional three-dimensional modelling/animation application (‘Max’) and Adobe Photoshop CS2, an image-editing program. In order of execution, the following steps were taken, illustrated in Figures 3a through 3e.

**Building the basic structure (a).** The previously acquired geometrical data was entered into Max, thus creating a basic referential model of the scene.

**Determining viewpoint parameters (b).** In order to properly contrast generated
images of the virtual scene with the original painting, camera parameters in Max were determined such that most of the groundwork—in any case the floor and the back wall—perfectly matched its painted counterpart in a camera view. Setting Figure 1d to the background of Max’s perspective view facilitated this. The camera was positioned near the entrance of the room, faced the ground at a six-degree angle, and featured a 45-degree horizontal field of view.

Adding further scene elements (c). With the foundational shapes in place and the scene viewpoint established, the shapes of the other objects could be added. They were modelled directly on their contours in Figure 1d (set earlier as a background image), ensuring a close match to the painting.

Creating and applying materials (d). Textures and other optical properties (such as roughness, translucency, and reflectance) were assigned to the surfaces of the shapes in the scene. Photoshop was used to create faithful material maps (images) for individual objects. Most of these were colour-adjusted, or otherwise tuned, versions of ones obtained from Internet sources, whilst others the author made himself, digitally painting them; still others were generated through parametric procedures in Max. Only a handful were extracted directly from the painting, since textures produced in this manner tended to lack overall quality.

Illuminating the scene (e). A number of point source lights of medium intensity were placed in both window openings, ‘fill lighting’ the room. A fairly strong target spot casting soft shadows was added at a distance outside, simulating weak sunshine. The area on the floor and the bed lit by this spot was further accentuated, or simulated to produce indirect light, by placing a few dim point lights over it.

Rendering images of the scene. Finally, images of the entire scene were rendered using Max’s Scanline Renderer, with the camera setup explained above. A cyclic process of rendering the scene and making careful adjustments to scene geometry, material properties and lighting produced the result shown in Figure 3e.

5 Comparing the result
Figure 3e is a final high-resolution rendering of the reconstruction model best matching the original
painting. It is taken from a position close to Van Eyck’s vantage point in the scene. Figure 4a is a rendering of another interesting view.

Figure 4b indicates the extent to which the author managed to adhere to Van Eyck’s original composition, while maintaining correct perspective geometry. It shows the painting’s essential contours projected onto the reconstruction image (Figure 3e), and reveals a sizable projection error in the upper parts of the composite. This result was anticipated since in resolving the inconsistency of the painting’s perspective (whilst retaining optimal coincidence), its geometrically more accurate lower portions were relied on.

6 Conclusions and further work

This article featured a virtual reconstruction of the interior space depicted in the Arnolfini Portrait. Implicitly, it demonstrated how any such painting with inconsistent linear perspective could be modelled in three dimensions with a fair amount of accuracy, using only traditional CAD tools. The advantageous computational methods by Criminisi et al. (2002) cannot be applied in cases like this.

There are various benefits and potential applications of the work presented here. A three-dimensional reconstruction of the painting provides insight into the spatial structure of the original scene, and so naturally may be of interest to art historians. Moreover, interactive exploration of such a reconstruction will allow people casually interested in historic art to experience the painting’s three-dimensionality more vividly. It may even captivate the young—who have grown accustomed to realistic three-dimensional computer imagery in cinema and video games. One might appreciate the possibility of looking at the painted scene from exciting new angles, and watching a fly-through video of the scene, as occluded spaces are filled in. In practical terms, a reconstruction of the painting could be used in an on-site or remote learning environment hosted by a museum.

Areas of further development include accurate modelling of scene characters, increase and refinement of details, and use of more advanced lighting and rendering solutions for enhanced realism. In a later stage, when interest arises, this work could be adapted to feature in a virtual learning application with special interactive capability. For the moment, it may serve as a helpful instrument in studying and correcting the painting’s three-dimensional composition.
Overview

- A three-dimensional virtual reconstruction of a painting with incorrect linear perspective calls for special interpretation of its spatial geometry and educated guessing of certain scene measurements.
- The reconstruction must therefore be performed ‘by hand’, using traditional modelling and image processing software, instead of existing innovative semi-automatic methods.
- A three-dimensional reconstruction of The Arnolfini Portrait with correct linear perspective, seen from Van Eyck’s postulated viewpoint, can remain highly faithful, yet illustrate geometric inconsistencies of the painting.

References


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Philip Jansen (22) is an Industrial Design Engineering major. In early 2007 he wrote a paper on this article’s subject for a course in his Arts, Media and Technology minor. In collaboration with professor Zsófi Ruttkay, the paper was improved upon and finally presented at the EuroGraphics’07 conference in Prague—where it was well received. As the article is largely based on this conference paper, the author wishes to acknowledge the efforts of professor Ruttkay.

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