Paolo Uccello's "Rout of San Romano": Order from Chaos

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Renaissance painters who pioneered linear perspective and the systematic representation of light, shade and cast shadows were, in their own precocious way, in the businesses of plotting forms in space according to three coordinates and of ray tracing. It seems natural, therefore, to turn to computer vision to analyse forms in spaces in Renaissance paintings. Generally computer analyses have been accomplished by the extraction of data from the painting and their feeding into a CAD programme. The results are only as good as the quality of the data extraction allows, and there is no automatic assurance that the CAD programme sits comfortably with the artist's original means.

The newer method of single view metrology has proved to work highly effectively with paintings, not least because it works directly from the painted surface to the spatial analysis, with minimal user interaction[1].

Given a perspective image of a slanted planar surface (e.g. a wall, the floor, the ceiling) it is possible to compute a geometric transformation (namely planar homography) that uniquely maps each point on the world surface onto a corresponding point on the image plane. The computed homography can then be used to measure distances, angles and object dimensions directly from the image plane; or to construct a new, rectified view of the observed surface (see fig. 4). Machine vision provides algorithms for the accurate estimation of the homography transformation and its compact mathematical representation. Furthermore, single view metrology provides techniques for the measurement of heights of objects and/or people[2].

By combining planar measurements with height measurements, single view metrology "removes" the perspective distortions which inevitably arise when imaging/painting a three-dimensional scene on a two-dimensional support. Consequently, accurate three-dimensional measurements can be extracted from single images such as photographs, drawings, and paintings. This process can be thought of as inverting the rules of linear perspective.

Single view metrology has proved its worth with paintings in which the perspectival clues are overtly

1. Antonio Criminisi. *Accurate Visual Metrology from Single and Multiple Uncalibrated Images*. Springer-Verlag London Ltd. Aug. 2001. ISBN 1-85233-468-1.

2. Antonio Criminisi, Martin Kemp, Andrew Zisserman. *Digital Art History: A subject in transition 2005* Bringing Pictorial Space to Life: computer techniques for the analysis of paintings A. Bentkowska-Kafel, T. Cashen and H. Gardner editors. ISBN 1-84150-116-6.

geometrical and prominent, such as Masaccio's Trinity and Piero della Francesca's Flagellation. However, when the depiction does not involve such obvious motifs as tiled floors and architecture, the perspectival techniques are necessarily more implicit and less immediately evident. It might seem obvious that landscape settings would not lend themselves to geometrical plotting. However, such was the conviction of some artists that there were underlying orders both in nature and in the act of seeing that every naturalistic representation demanded a systematic plotting of forms in space.

Figure 1. Paolo Uccello. The Rout of San Romano. ca.1440. National Gallery, London.

Paolo Uccello is probably the most notorious advocate of this stance. His supposed retort to his wife when nagged to come to bed – "what a sweet thing is perspective" – is an established part of artistic myth. His works testify to the spirit of this anecdote if not its reality. When the Hunt in the Forest in the Ashmolean Museum in Oxford was scientifically examined in 1990, a "ghost pavement" was discovered in the underdrawing on the white priming of the panel[3]. The "pavement" provided the sliding scale for relative heights of the figures, horses and dogs into the depth of the notably columnar forest.

Recently, working on the Television Programme, "The Private Life of a Masterpiece" for BBC TWO, transmitted on 16 April, we looked at Uccello's Rout of San Romano (fig. 1) in the National Gallery in London (one of three companion paintings of the 1432 battle). In this instance, no "ghost pavement" has yet been detected through scientific examination, but the painting itself contains telling clues that such a "pavement" did indeed provide the armature for

3. Martin Kemp and Anne Massing, 'Paolo Uccello's Hunt in the Forest', *The Burlington Magazine*, CXXXIII, 1991, pp. 164-78

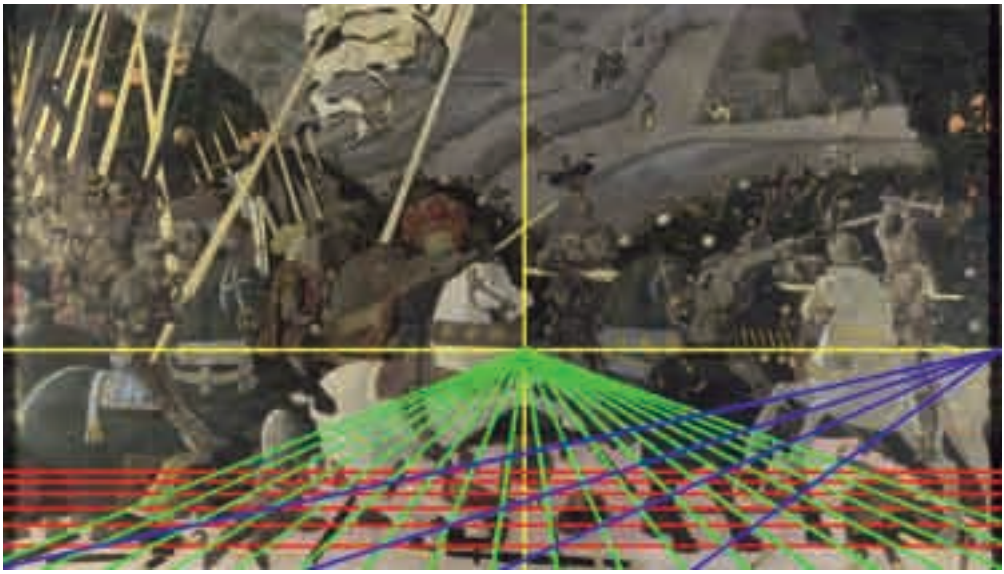

Figure 2. Geometric reconstruction of the ghost pavement (green lines) and distance point (blue lines).

the scaling on the foreground stage. The clues lie (literally) in the artfully arranged lances on the ground, a significant number of which have fallen conveniently along the lines of the implied "pavement. One, in the lower right quarter of the ground, has fallen along one of the diagonals of the implied squares. Such diagonals are known to have provided Uccello with one of his prime constructional tools, using the laterally disposed "distance points" (fig.2)[4].

4. Martin Kemp, *The Science of Art. Optical Themes in Western Art from Brunelleschi to Seurat*, Yale University Press, London and N ew Haven, pp. 37-41

Figure 3. The rectification process applies only to objects lying on the ground plane. Therefore, before rectification is applied we need to mask out all the objects which do not lie on the floor. This process eases visualization.

Figure 4. The rectified floor. This image shows the ground plane as it would appear if seen from above.

Figure 5. The rectified floor. In this figure the red/green grid of figure 2 has been rectified together with the ground plane. Now the grid is made of perfectly square elements which can be used as measurement unit. The dead soldier is approximately four units tall.

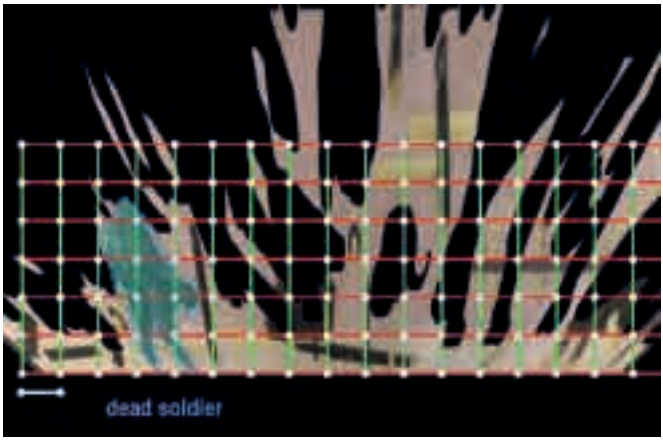

Figure 6. The same grid units of fig. 5 can also be used to measure heights. Niccolò da Tolentino is approximately four units tall, consistently with what found in fig. 5. Interestingly, the whole knight and horse figure is inscribed in a 6x6 square grid.

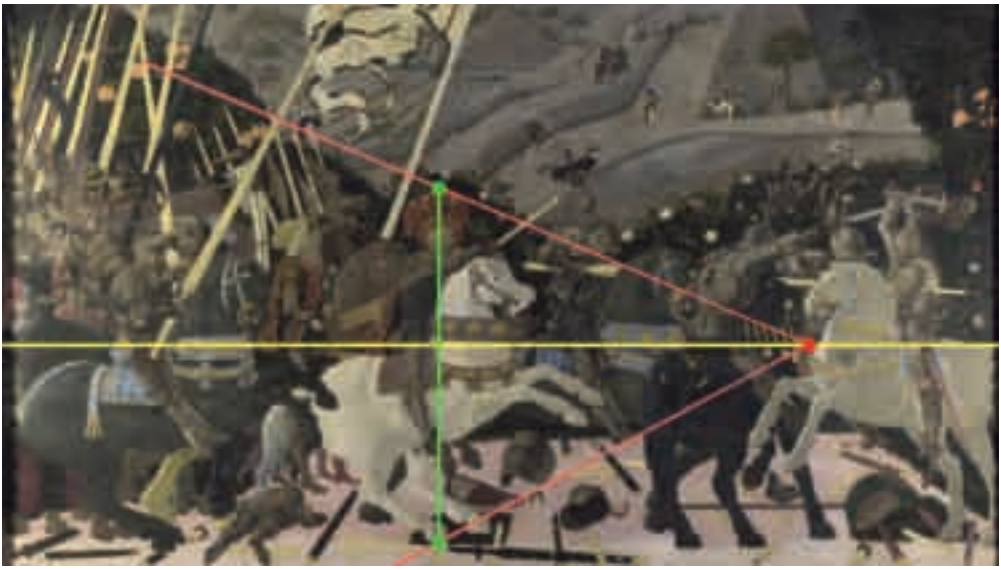

Figure 7. The red point shows the direction in which we wish Niccolò da Tolentino and his grey horse to move.

The evidence is not such as to provide cast iron evidence of the precise disposition of the "ghost pavement", but the one we are proposing is the kind of construction that would have existed under the paint surface or in a scaled drawing. Some items in the debris lie slightly off-line, no doubt to avoid what even for Uccello would have been excessively improbable tidiness.

The detection of this underlying regularity provides the basis for the rectification of the ground plane with its organised debris of the lances and the fallen warrior, who lies slightly off the relevant orthogonal in the implied grid (figs 3-5). In this case the rectifying homography was accurately computed from reference points provided by the grid structure of the estimated ghost pavement.

If the modules of the grid are used for the purpose of analysis to judge the scaling of the horses and riders (fig. 6), we find that the scaling of the combatants is generally consistent with the recession of the "ghost pavement". This is confirmed by the animation in which the Florentine commander. Niccolò da Tolentino, and his grey horse are slid diagonally backwards into the painted space in a predetermined direction (figs. 7-8). The effect may be likened to the moving of pieces on a chessboard when viewed from a relatively shallow level – in this case along a horizontal level close to the horses' backs.

Where Uccello has most conspicuously not followed the logic of his construction is in the more distant landscape, in which scattered warriors indulge in various pre- or post-battle activities. He has combined his measured foreground

stage with a landscape backdrop that functions well for pictorial purposes without attempting to establish any optically consisitent realtionship between them.

What Uccello has achieved is a fine balance of decorative complexity and geometrical order, as was fitting in a work which served as part of a decorative ensemble in a domestic palace (originally of the Bartolini Salimbeni family and later of the Medici) and as a patriotic rendering of the famous Florentine victory. Decorative chivalry was a real feature of Renaissance battles, but commanders would have killed to achieve such spatial order in an actual engagement. ■■■

Figure 8. The geometry computed for the ground plane allows us to make Niccolò da Tolentino and his horse move back and forth in the direction of choice in a realistic way; i.e. in a way which is consistent with the overall geometry of the painting.