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Three-Dimensional Perception, Measuring Reality

Joaquim Salvi

This article is about developing techniques that enable a machine to recognize and interact with its environment. Humans use two eyes to perceive three dimensions. Similarly, we use digital cameras to perceive and program algorithms that attempt to emulate the human brain in order to recognize and measure the reality that surrounds us.

Keywords: 3D, Reality, Vision.

Author

Joaquim Salvi leads the 3D Perception Lab as part of the Computer Vision and Robotics group of the *Universitat de Girona*, Catalonia, Spain, with more than 60 researchers from different countries. The 3D Perception Lab focuses on the analysis and study of different projection techniques and visual image capture to obtain information about the volume of a particular object. He has directed several research projects and technology transfer projects for companies, and is an inventor and holder of an international patent.<qsalvi@silver.udg.edu>

1 Different Ways of measuring Reality

The 3D Perception Lab has worked since its creation in 1997 in different areas of 3D artificial vision research. The most important are three-dimensional stereoscopic vision, structured light and structure from motion. Stereoscopic vision uses two cameras, as if they were two artificial eyes, to simulate human perception. The cameras capture both images, which are then aligned and the third dimension is extracted from the parallax between the corresponding points. At the end of the procedure a three-dimensional visualization of the scene is obtained. The crucial point in this case is obtaining enough corresponding points, directly related to the visual "wealth" in colours, textures and shapes of the scene meant to capture. Structured light uses an active device (a video projector or a laser beam) together with one or more digital cameras. The objective sought by this method is to increase the texture of the object to be measured, ie. the visual details projected by the projector are reflected by the object and captured by the camera. The end result is like having a stereoscopic vision system in which the object has a lot more texture, so the three-dimensional information we collect is richer and reconstruction may be more accurate and complete, with obvious business interests, especially in three-dimensional quality control of manufactured parts, but also in the biomechanical analysis of our body, either by analysing the ways to develop orthopaedic shoe soles specifically for each individual, or by measuring deformations in the spinal column to correct posture problems.

These fields of research have been developed, and are still in development, through 10 doctoral theses associated with many different research projects. Currently, Sergio Fernandez is doing at the *Universitat de Girona* (Catalonia, Spain) a PhD on the three-dimensional reconstruction of moving objects using dense pattern projection of structured light. Up until now, reconstructions using structured light had little detail if used to measure free-moving objects, while techniques based on measuring static or mechanically-controlled moving objects abounded. With the technique that Sergio is investigating, the accuracy and completeness of static analysis is being achieved, but with the advantage of being applied to moving objects, which greatly opens up the fields of application of 3D reconstruction to the analysis of faces or objects in movement with high accuracy, which can be applied in the manufacturing industry, security companies, the creation of interactive video games, etc.

The third 3D vision technique mentioned, structure from motion, uses a single digital camera, and is based on analysing the trajectory of an object along a sequence of images to extract the three-dimensional structure of the object and its movement in three dimensions. Luca Zappella is the investigator for the group that, co-chaired by Joaquim Salvi and Xavier Lladó, is developing a new structure from motion technique at the above mentioned *Universitat de Girona*. Although it may sound strange, it is important to note that some animals, such as pigeons, base their knowledge of their 3D environment on the same principle. As you see, nature is an unending source of ideas for artificial vision.

2 Structured Light, a Business Experience

It is worth mentioning that the PhD theses of Josep Forest (2004) and Carles Matabosch (2007), both dealing with structured light, were the starting point for the company AQSENSE SL, whose founding partner is the author of this article.

The company AQSENSE begin to take shape in 2005 and was established in 2007 with the aim of commercializing the technologies developed during the elaboration of the above mentioned PhD theses. Josep Forest developed a calibration method and a laser peak detector, while Carles Matabosch developed a method of three-dimensional registration between scans. Both theories combined allowed to develop a complete reconstruction of three-dimensional objects.

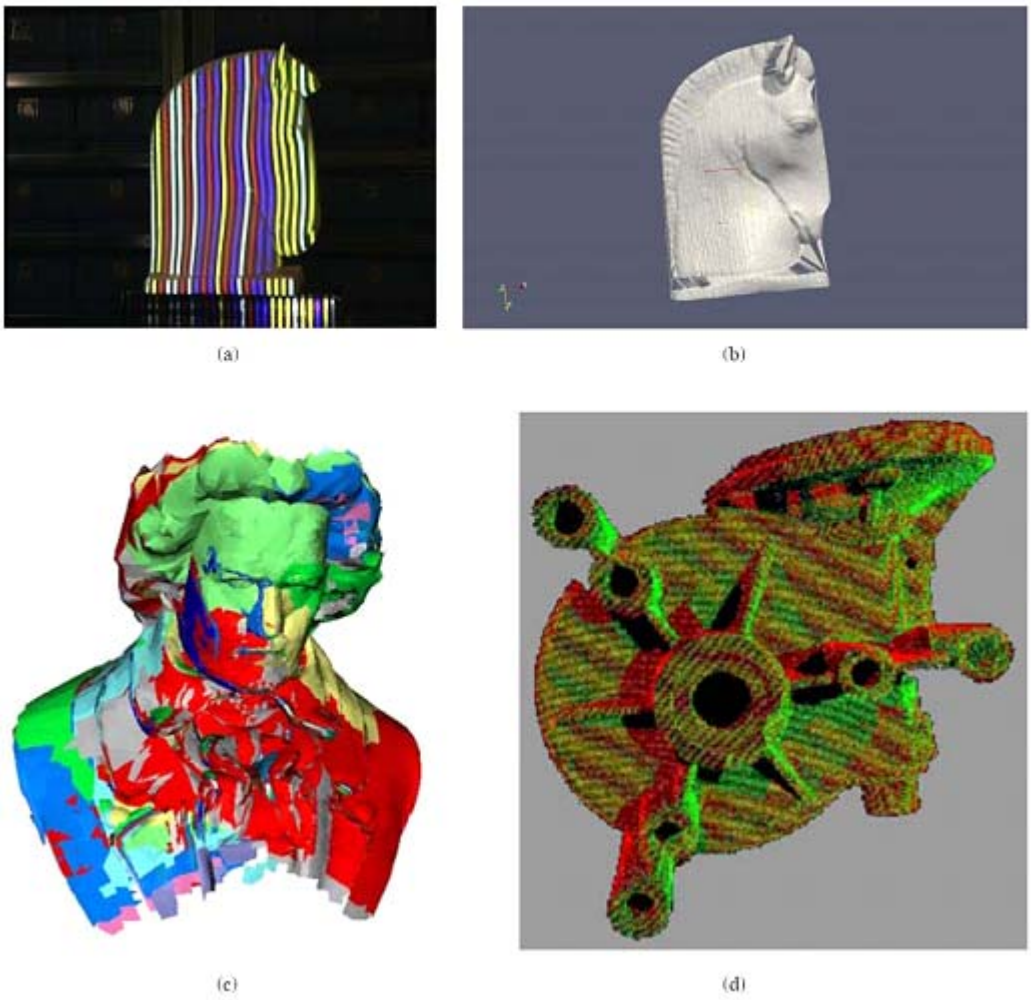

Figure 1: Results of the different techniques described in this article: (a) Image of a plaster horse head with the projected light pattern; (b) Three-dimensional reconstruction of a plaster horse head; (c) R Multi-view registration for complete reconstruction of three dimensional objects; (d) 3D registration of a manufactured part with its three-dimensional model for quality control applications (courtesy of AQSENSE SL).

The research team had the firm belief that these technologies could be an important step forward. The objectives of the company were to obtain greater accuracy, processing speed, strength, flexibility and ease of use than the techniques existing at the time. Laser capture, combined with a refined algorithm for filtering and alignment of 3D points, produce three-dimensional reconstructions with precision and detail coveted by most existing 3D scanners to date. Currently, AQSENSE has 10 employees and its products are available worldwide through Stemmer, Parameter, IRIS Vision and Infaimon.

3 Future Strokes in 3D Reconstruction

Today artificial vision requires real-time applications. That is why 3D reconstruction techniques of the future must be able to work with moving objects and objects with mirror image surfaces and highly-reflective surfaces (mirrors, metals), providing instant three-dimensional results that can be used interactively for 3D quality control on the production line, for realistic immersion applications in video games and for biomechanical analyses of the human body in developing specific prosthetics and orthopaedic soles. We can therefore say that the research described in this article has a lot of potential for the development of 3D vision.