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Abstract

Fast, high precision and automated optical noncontact surface profile and shape measurement has been an extensively studied research area due to its many potential applications including 3D sensing, industrial monitoring, mechanical engineering, medicine, robotics, machine vision,animation, virtual reality, dressmaking, prosthetics, ergonomics. Among others, structured light approaches including fringe profilometry have proven to be one of the most promising techniques. In such profilometry techniques a structured light pattern, generally composed of parallel lines is projected onto a diffuse surface to be measured and viewed from an offset angle. The observed pattern is distorted by the object in such a way that represents information about the height of the object perpendicular to the plane of observation. The distorted structured light pattern is recorded, commonly by a CCD camera and through computer analysis of the recorded image the object can be recreated in 3D space, typically with a high degree of precision.

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Optimisation of Triangulation Based Optical Profilometers utilising Digital Video Projection Technology

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Fast, high precision and automated optical noncontact surface profile and shape measurement has been an extensively studied research area due to its many potential applications including 3D sensing, industrial monitoring, mechanical engineering, medicine, robotics, machine vision, animation, virtual reality, dressmaking, prosthetics, ergonomics. Among others, structured light approaches including fringe profilometry have proven to be one of the most promising techniques. In such profilometry techniques a structured light pattern, generally composed of parallel lines is projected onto a diffuse surface to be measured and viewed from an offset angle. The observed pattern is distorted by the object in such a way that represents information about the height of the object perpendicular to the plane of observation. The distorted structured light pattern is recorded, commonly by a CCD camera and through computer analysis of the recorded image the object can be recreated in 3D space, typically with a high degree of precision.

In traditional triangulation based optical profilometers interferometric methods using a laser source are used to project a structured light pattern onto a diffuse object to be measured. An alternative to conventional laser projection is Digital Projection (DP). DP provides the ability to manipulate patterns quickly and easily with high precision in software, along with the capability to develop multi-channel algorithms via colour pattern projection. With the growing demand for high speed 3D profiling for applications such as animation, face recognition, machine vision etc, we have seen profilometry utilising Digital Video Projection (DVP) quickly becoming the standard in profilometry arrangements, with more and more researchers adopting the technology on the merits of higher resolutions, contrast ratios and sharper images all of which are characteristic of the highly developing projection technology. These incentives have fueled continued interest from the research community over recent years, however, in contrast with the classic analogous laser source, the discrete nature of the digitally projected structured light pattern lacks in contrast ratio and pattern density, henceforth, imposing a theoretical limit on the spatial accuracy of the metrology system. Spatial resolutions achieved by profilometers utilising laser generated grating patterns are typically limited as a result of the capture device. Conversely, when DVP is utilised the accuracy of the metrology system becomes a function of projector characteristics and varies across the surface of the object being measured (assuming the capture device can adequately capture the projected grating).

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This limitation was first recognised by Huntley and Saldner [1] in their analysis of temporal phase unwrapping, a technique well suited to DP due to the associated flexibility in fringe map production and was revisited again by Coggrave and Huntley in [2], where they proposed a defousing optimisation scheme. This scheme aimed to increase the spatial resolution of the projected image by adjusting the focus of the projection source. A sinusoidal fringe pattern was projected onto a reference plane and the phase error was measured whilst varying the focal distance of the projector. This analysis assumed that the focal plane of the projector and the reference plane were parallel, which in fact is not true when projecting from an angle, this resulted in non-uniform focusing across the measurement scene when considering that a standard digital video projector utilises lenses that are designed for orthogonal projection onto a flat surface. As a result of this non-uniform focusing, defocusing optimisation schemes become angle dependent and consequently particular optical configurations can prove more optimal than others.

In this work we propose an optical configuration to increase the spatial resolution of triangulation based profilometers utilising DVP and also facilitate increased performance of defocusing optimisation schemes such as presented by Coggrave and Huntley in [2]. We demonstrate the performance of the proposed optical configuration by contrasting experimental results obtained from a typical triangulation based profilometer optical configuration. Firstly we show that a more uniformly sized pixel distribution can be obtained through the proposed arrangement and secondly we demonstrate increased performance for defocusing optimisations schemes discussing the angle dependencies involved in optical configurations. The results confirm the usefulness of the newly proposed optical configuration for triangulation based optical profilometers utilising DVP.

References

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