Recent Improvements in Photometric Stereo for Rock Art 3D Imaging

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Abstract

A 3D reconstruction technique, used for documentation, should have four main important features: cheapness, practicality and limited acquisition and elaboration time. At the state of art, one of the best 3D reconstruction technique, in term of quality of result, is the "laser scanning" which it is not cheap and suitable for all archeological applications. In that sense a concrete alternative, especially for 3D Rock Art documentation, is represented by "Photometric Stereo" . The methodology is based on *Lambert's cosine law* which substantially affirms that it is possible to obtain a 3D semi profile of a surface represented in some pictures taken in a different light condition.

Equipment

Acquisition process

➢**Simple and fast**: you have only to place the camera and shoot some pictures changing, for each one, the flash position.

Algorithm and mathematical concept

➢Starting form the pictures, the first step is represented by the gradient extrapolation. This because one of the main information that we lose when we take a photo is the depth, that is an important 3D requirement. We can achieve it by studying the respond of the object to several lights excitation writing a particular *spherical harmonic decomposition* that can be applied using *Principal Component Analysis* (TSVD). A mathematical constraint imposes the minimum number of pictures must be 3, but for better results we use a bigger number to have always overdetermined problems.
➢The second step consists of the integration process. In fact the gradient is a discrete function, so to obtain the final 3D shape we need to integrate it. To do so we solve a linear system that derives from the use of finite differences method applied to the two dimensional Poisson's equation. In our initial experiments, this phase was critical in term of computation time. We have fixed this issue optimizing the process and we are now able to obtain results, working at high resolution, in just few seconds.

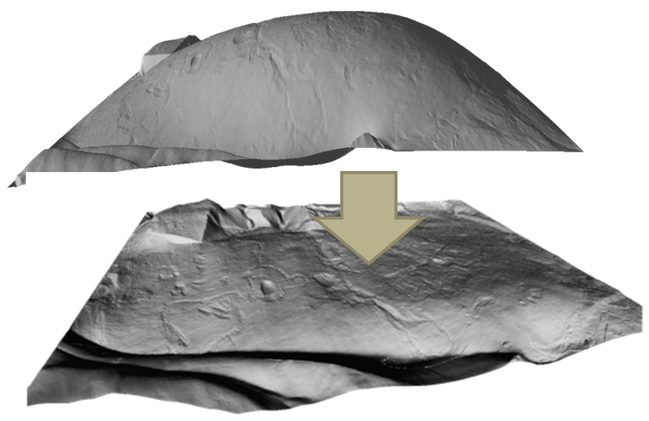
Results…

➢3D model of "man of Anela*", Sos Furrighesos necropoli*, Sardinia.

With and without albedo

➢Visualizing surface without albedo, allows the user to see more details which normally cannot be seen.

Planarization of surfaces



➢The ideal condition excepts the use of lights positioned at infinity. This constraint cannot be met also because light generated by flash is not perfectly uniform. The non ideality leads to 3D distorted reconstructions.
➢We are now able to stretch the surfaces, applying a postprocessing technique which is based on TSVD factorization.