An Active Vision System for 3D surface Color Measurements

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Common surfaces have reflection characteristics that differ considerably from those of a reference standard for colorimetry. They are neither totally diffusing nor regularly reflecting, and their reflectance strongly depends on the viewing angle and the illumination geometry. As a consequence, reliable measurements can be achieved only if the measuring geometry is fixed or known. To solve this problem, the Commission Internationale de l'Eclairage (CIE) recommended four standard geometries, defining both irradiation and observation conditions. Unfortunately, when dealing with 3D objects, with large dimensions in space, like for instance monuments or automobiles, geometry can hardly controlled and new-concept instrumentation is needed to obtain results reproducible in different times and/or locations.

Traditional instrumentation on the market rarely offers colorimetric and geometric measurements combined in a single device and when it happens one function is just a support to the other without any accuracy indication. In fact, accurate geometric and colorimetric data permit detecting changes of surfaces at a given resolution (e.g. erosion, mould growth, chemical alterations, …) when these data are strictly correlated for effective surveying analyses. Moreover, the assessment of the measurement accuracy would allow establishing a possible correlation between the geometric and colorimetric data of surfaces and the chemical-physical changes of the surrounding environment with a number of possible implications of interest.

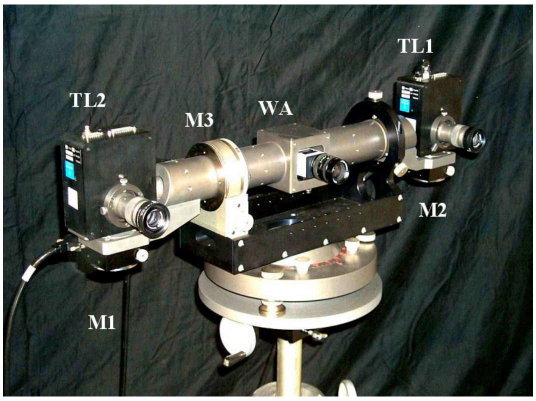
Concerning geometric measurements, devices and techniques for the acquisition of three-dimensional structures can be grouped in three categories: topographic, photogrammetric and laser-based techniques. Due to their physical working principle, each of them has a specific range of operation within which it supplies its best performances. In particular, all techniques merged together leave almost uncovered the range from two - three meters to twelve-fifteen meters.

Concerning colorimetric measurements, techniques and devices on the market can perform accurate measurements on single spots of at least some mm in size, or more. Colorimeters can be roughly grouped in two categories based on their measuring characteristics: in-contact and not in-contact. In-contact devices are equipped with an internal calibrated source of light while the other ones need external sources of light, possibly satisfying CIE recommendation on their spectral content. Even if all devices require less than some seconds to carry out a single measurement, the dense sampling of a surface can be very time-consuming because of the time needed for repositioning. In addition, the color-to-geometry correlation is not immediate and can be difficult establishing it.

In this context, there is a definite demand for a flexible, multifunctional (geometric and colorimetric) instrumentation which should integrate the traditional peculiar ones to easier the on-site data collection and promote its diffusion. The Active Vision System (AVS) described in this paper has been designed and developed to answer these needs. AVS works over a range from two to ten meters in depth and carries out integrated colorimetric and geometric measurements with assessed accuracies. Thanks to its computerized control for the automatic management of the operations, it allows the in-field processing of the acquired data and their comparison with databases for monitoring purposes.

The global functions of the SVA are essentially: the ***measurement of the 3D position of a point in the scene*** of the imaged surface and the ***measurement of the tristimulus values*** of this point. Then, the whole large scene is reconstructed with high resolution by scene tessellation and image mosaicing, and the 3D surface is obtained from sparse points or by dense reconstruction from the stereo TLs images. All these functions are automatically performed under computer control and a man-machine graphical interface has been developed for managing the whole system easily. The acquisition and registration of accurate geometric and colorimetric parameters concerning a given survey, such as the relative position between AVS and scene, the spatial co-ordinates of the test points, and the spatial position of artificial light sources, allow the system to carry out automatic and accurate repetition of that survey in successive measuring campaigns.

AVS is composed of three B/W TV cameras aligned along a common axis γ (see Fig.). Two of these cameras (TL1 and TL2) are equipped with long focal-length lenses to frame only small portions of a scene at high resolution. They can be rotated by known angles both around the parallel pan axes $\alpha_1$and α_2 and the tilt axis γ, to perform the fixation of some points of a scene. One TL is equipped with spectral filters, allowing the acquisition of high accuracy colour images of the examined surface. The third camera is equipped with a wide-angle lens (WA) to frame the whole region of interest at a lower resolution.



When the field size framed by TL cameras is too small for analysis, a wider field can be acquired as a sequence of partially overlapping tiles by automatically scanning the Region Of Interest (ROI) with TLs. The ROI can be interactively selected by an operator looking at the WA image on the computer display. In addition to texture and colour information, the spatial position, orientation and gaze direction of each tile are acquired at each step so that the entire framing geometry is completely controlled by the system and can be saved for reliable repetitions of the measurements at different times, i.e. for monitoring tasks. The reconstruction of the whole ROI information is obtained by image mosaicing. The mosaicing procedure differs from the ones described in literature mainly because the transformation of the acquired images is aimed at compensating systematic acquisition errors and parallax effects independently of the image contents, and not at minimizing the matching errors between adjacent images. Therefore, this method is intrinsically non-iterative and offers the advantages of being simple and fast, but accurate enough to satisfy the application requirements.