

## **A STUDY ON CLOSE-RANGE PHOTOGRAMMETRY IN IMAGE BASED MODELLING AND RENDERING (IMBR) APPROACHES AND POST-PROCESSING ANALYSIS**

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### **Abstract**

Photography rendition is an exercitation of photogrammetry, as commencing peculiarity (qualitative) information of images has significantly disseminated in an uprising technology and science. Additionally, digital cameras are presently exercised, as a modern conveyance tool that render an opportunity in capturing the photographic images instantaneously. The utilization of photographic images in the remake of 3D model acquires various interdependent techniques. Fundamentally, this photogrammetry methodology is called the image-based modelling (IBM), as the approach exercises projective characteristics of imagine to fashion geometric forms. On that basis, image-based rendering (IBR) is a method of creating new outlook from arbitrary camera placing in the absence of feature stitching however, by images recognition. These procedures are rendered in photogrammetry software beforehand exporting to several computing platforms within the vicinity for further refinements and simulation analysis. At length, the results and investigation of this study will be tendered in this research, as the subsequent post-processes.

Keywords: Image-based system, Photogrammetry, Photography rendition, Stitching.

## **1. Introduction**

Photogrammetry is an applied science and technology that practices dependable features and environs data acquisitions through elucidation of multiple photographic images. Photogrammetry is almost as dated as photography alone, which has shifted from analog to logical reasoning and digital techniques based upon the advancement in computer-aided design of algorithmic program [1]. Additionally, this current trending technique is the fundamental of ensuring accurate and detail measurements of three-dimensional subjects from the resulting two-dimensional photographs [2]. Therefore, prior to any design or a renovation project, it is essential as well as convenient to work with photogrammetry by capturing these existing conditions [3]. However, traditional method of surveying is painful, time-consuming and tedious. Nevertheless, multiple trips to the working area or examinations of a subject and manual capturing methods can lead to schedules that will be over-running and base information that is often incomplete or inaccurate [4]. Consequently, these inaccuracies may contribute to a number of negative impacts in terms of time, money and one's endeavors [4]. Fortunately, photogrammetry techniques are changing the way of surveying via a procedure that captures, measures and maps millions of surface points with highly detailed texture in sequence of reconstructing precise and quality 3D models [5].

Nowadays, there are innumerable occasions in life or science, whereby quantification such as distances, areas, volumes or co-ordinates are imperative and in several juncture, it may be difficult to compute or synchronize with research and development. Conventionally, tools such as tape measure or a foot rule will be utilized, however, photogrammetry techniques yield an alternative approach for measurement without proposing any physical contact to the subject.

In several occurrences, the practice of assessment relies on the nature of the subject. For instance, if the subject itself neither exhibits nor exists any longer but only of photographs, thus, photogrammetry is the practical companion in acquiring desired data or information. Also, photogrammetry techniques are feasible for areas or landscapes that are not deftly reachable or without an adequate infrastructure. Moreover, at the present time laser scanner 3D and 3D printer instrument is an auxiliary to photogrammetry [6, 7]. Additionally, the close-range photogrammetry technique is outspreading promptly in acquiring qualitative data of 3D point data (point clouds), as laser scanning and 3D printing are time consuming and costly comparatively [6-8]. Therefore, this advantageous modus operandi can be seen as an adjunct to photogrammetry techniques, whereby one of the significant benefits is that measurements are technically obtained from multi images [8].

On the other side, the ability to develop 3D modelling from the captured 2D photographic images is a noteworthy feature. Therefrom, these documentations of images can be revised again for future works as well as shared with other researcher and also easily kept in computers [3, 7, 9]. However, capturing perfect photographic images comprising of all detailed textures and features is a troublesome for beginners as well as professional photographers [9, 10]. On that note, this paper emphasizes to investigate shooting strategies for digital close-range photogrammetry technique in a 3D model from literature. Therefore, in acquiring higher quality and precision modelling, photography procedure techniques are vital

to be comprehended. In this study, a procedure during photogrammetric is presented as in Section 2, continued with a case study on a small-scale subject in order to verify the presented photogrammetric procedure in Section 3, and conclusion of this study in the last section.

## 2. Photogrammetric Procedure

Crawford [6] mentioned that the utilization of photographic images in the remake of 3D model acquires various interdependent techniques as it is portrayed in Fig. 1. Additionally, according to Kolecka [7], this phenomenon-based methodology called the image-based modelling and rendering methods (IBMR) or photometric modelling is a computer graphics and a computer vision in recognising, clustering and uprooting features akin to faces, edges and patterns portray in a set of images beforehand rendering them as a three-dimensional conceptual visualisation.

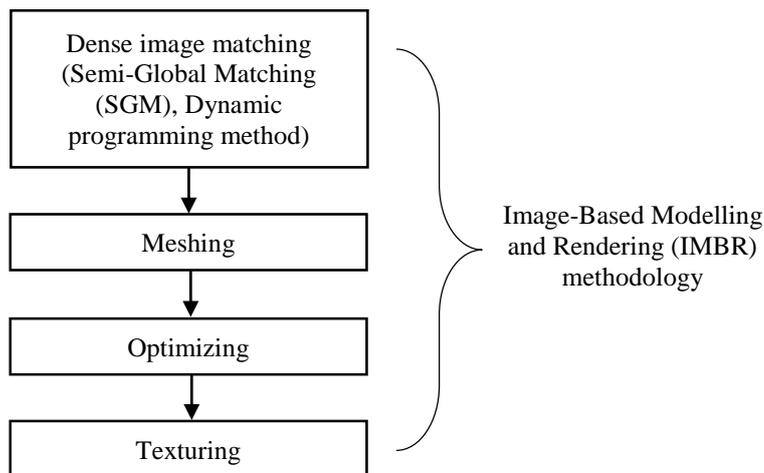


Fig. 1. Workflow in guided image capture and pre-processing system.

## 3. Case Study

### 3.1. A small-scale subject examination that portrays as a case study

Therefore, the photometric modelling method is executed in an inspection on a clutch master cylinder as portrayed in Fig. 2 that represents a case study in verifying the eminent skills methodology of the techniques for post-processing interpretations.

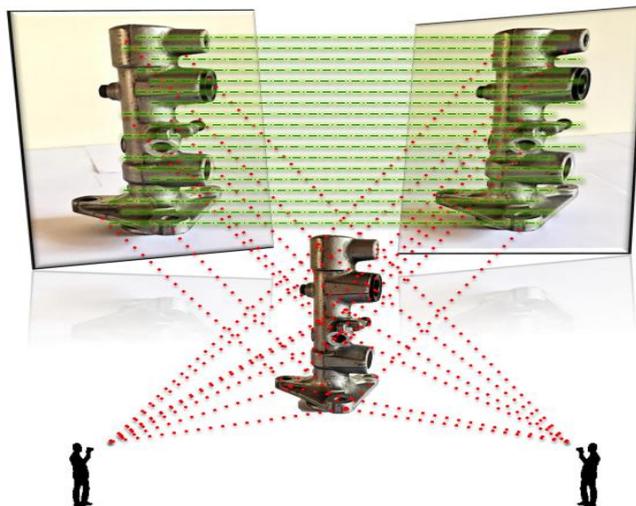
### 3.2. Image-based modelling and rendering (IMBR) approaches

Baltsavias [8] proposed the primary procedure in creating a thorough 3D model peculiarity is to algorithmically compute a dense point cloud of an examine subject. Fundamentally, these data points in space are rectified through a dynamic dense pairing operation between oriented photographic images that outgrowth in overlapping pictures and exposures to yield better results. This straightening method is described as image matching or feature stitching technique commencing from similar points recognition from the captured scenes, as depicted in Fig. 3 [9]. Comprehensively, these approaches are executed and

optimized in any photogrammetry software, which utilizes modern Semi-Global Matching (SGM) stereo technique in perceiving identical pixels from a pair of photographic materials.



**Fig. 2. A clutch master cylinder utilized for a photogrammetry model as a case study.**

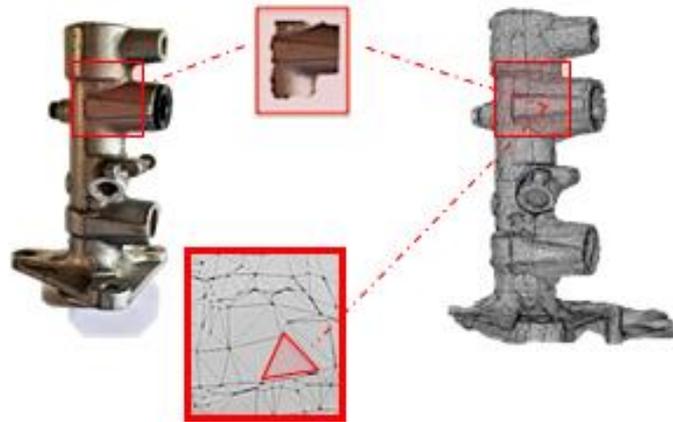


**Fig. 3. Feature tie points recognition in 3D space.**

Additionally, this auspicious technique is not affected by the variety of parameters and is robust against radiometric data. On that account, the SGM technique is ideally suited for most problem-solving methodologies and applications such as the 3D reconstruction purposes [10].

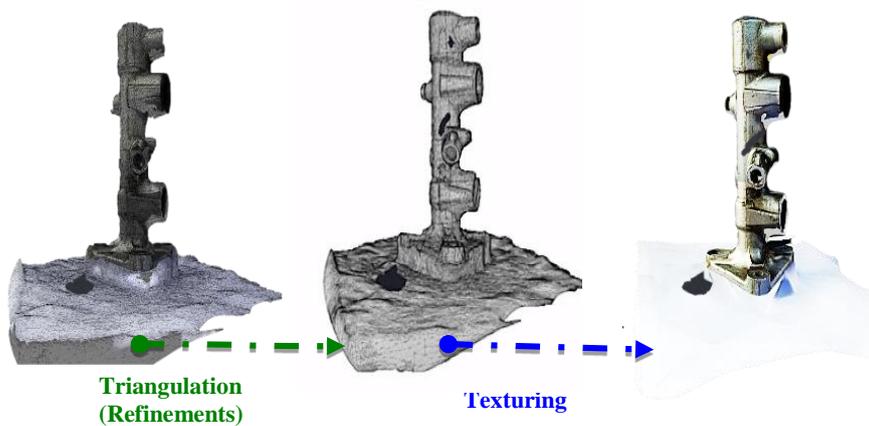
Consequently, the 3D triangulated surfaces from the prior originated point cloud instigate meshing and texturing phases of the final digital workflow progression [11]. These triangulations of a modelled surface, as depict in Fig. 4 are a network of triangles that shroud the model surface entirely or partly throughout a polygonal meshing method known as tetrahedralisation [11].

Therefore, the fabrication of a precise and reasonably pragmatic textured three-dimensional model is practicable. Fundamentally, based on studies by Remondino et al. [12], a dense point cloud is generated, whereby it compels to accomplish a dense pairing between oriented photographic images. Thereafter, texturing is a definitive procedure in which, the software outlines digital colour image onto the 3D triangulation surfaces and thus, portraying a photorealistic representation [11, 13].



**Fig. 4. Surface triangulation of the implicit model surface.**

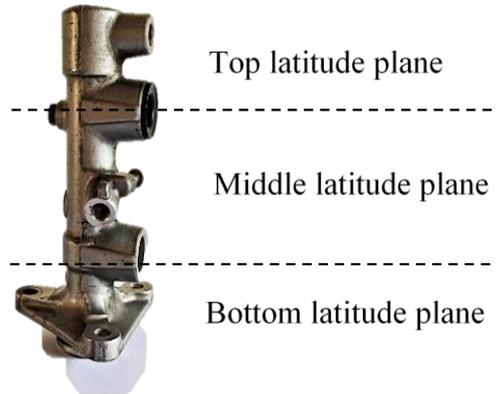
Additionally, the images quality during the acquisition stage acts as the most vital criteria in enhancing and archiving better reconstructions outcomes in the post-processing phase [14]. This is because the data with regard to the textured 3D model is wholly transfigured from the 2D images acquired and therefore, higher quality images rendered better texture surfaces for eminent 3D model reconstruction Herein, a graphical illustration, as depicted in Fig. 5 portrays the sequence of phases of the digital workflow process [15].



**Fig. 5. Digital workflow in 3D textured model.**

### **3.3. Mesh generation**

The model domains have been extracted from three different latitudes (heights). Fundamentally, improvement on the methodology is studied in which, dependent parameters are developed to enhance image-modeling process. Therefore, Fig. 6 shows the obtained generated meshes.



**Fig. 6. Three different latitudes of images acquisition from a clutch master cylinder as a photogrammetry model.**

### **3.4. Outsourcing photogrammetry metadata via supported file formats**

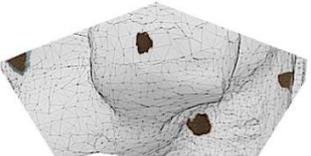
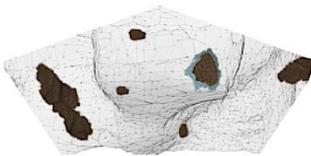
The photogrammetry software exerted for the reconstruction of the 3D spatial data visualizations throughout this investigation is termed as Autodesk Recap.

Additionally, the created 3D dataset from the Recap are thereupon exported into another modelling software programs for further analysis and simulation in the format of STL and .OBJ files [16]. Primarily, the files generated in Recap are in the form of .OBJ, RCM and RCP, whereby the .OBJ file format is commonly utilized by wide application of practices [17]. These software programs such as ideaMaker, Autodesk Meshmixer, Autodesk Inventor, 3D Builder, SolidWorks, LISA and so forth assist and suffice a model polygon count for an absolute 3D printing operation, advance refinements, surfacing and solidifying model, editing drawings and features, various analysis performances, sustainability and preface remarks respectively [16].

### **3.5. Comparisons between both shooting strategies in photogrammetry**

The examined subject has been shot with a complete of 80 photographic images for every photography session undergone, as a fixed variable during a run of the modelling workflow. Furthermore, similar camera frame settings as well as environment set-ups are utilized during the acquisitions and therefore, spot colours, blemishes and shadows (if any one of these or all) are not disclosed or spreaded over an area at different coordinates in the imaging for fair outcomes in each reconstructed model in Recap. Herein, Table 1 tabulates the comparisons in the outcomes for both shooting strategies-based approaches in photogrammetry.

**Table 1. Comparisons of both approaches from 12-megapixel acquisitions.**

Distinction characteristics	Photogrammetry shooting strategies	
	Turntable approach	Rotating camera approach
<b>User-friendliness and photographing practice</b>	Provides more convenient and faster manner to use with lesser photographing interferences and more precise in angularity between images.	Tedious to move the camera around the subject with potentially more photographing interferences, as to the shakiness and not precise in angularity between images.
<b>Mesh visualisations</b>	 <p>Modelling via imaging from a turntable approach.</p>	 <p>Modelling via imaging from a rotating camera approach.</p>
<b>Number of holes formed during meshing process in digital workflow</b>	 <p>Fewer and smaller holes are formed via turntable approach.</p>	 <p>More and larger holes are formed via rotating camera approach.</p>

**3.6. Exporting to solidworks for simulation analysis**

In conjunction with the generated metadata of the three-dimensional model from photogrammetry software, the corresponding features alongside with the characteristics are to be improvised further for SolidWorks to be able to read a non-native file format [18]. Subsequently, the exporting files are saved as an STL file type however, the number of polygon counts is to be refined before now to an acceptable quality and number in which, SolidWorks is capable of importing the model as a solid part [18]. Otherwise, either the software crashes completely or the model is brought in as a body that apparently to have no faces or edges that can be selected as well as no operations that can be performed on it (known as STL graphics body) [19]. In Recap, decimating model feature is available but for a better mesh editing purposes in a manner of mesh iteration and smoothing strength an intermediate processing is a consideration via several computing platforms [20].

Consequently, after the reduction of rendered polygons to appropriate triangular faces, importing a model as a solid part is possible in SolidWorks.

After the model with the simplified meshes is successfully exported into SolidWorks, the software solid modelling capabilities is pursued in furtherance. However, rescaling the solid 3D model into similar or approximately close to the size, mass and dimension of the actual subject is essential in SolidWorks. The reason for this is because the generated triangular mesh from an examined subject has multitudinous count of faces with certain volumes, surface areas and degree of freedoms, which is also affected by the quality of image acquisitions. Therefore, when the 3D model is evaluated in the SolidWorks after through the actual material is applied, the mass displayed is tremendously large although the meshes have been decimated. Hence, rescaling is a factor to be considered if true size is needed for an absolute analysis.

Also, to experience .STL files in SolidWorks, it is vital to comprehend that there are limits to the levels of complexity that SolidWorks can handle. On the other side, importing .STL files by utilizing the import options enable user to control on the types of bodies that SolidWorks attempts to form when opening the file promptly. Hereto, start by clicking on the file open dialog box and to access the STL import options, change the file type in the drop-down menu to STL. After, with the .STL file type being selected there is now an option button that can be assessed to pick the options as to import the file as a graphics body, solid body, or surface body. Therefore, Fig. 7 illustrates the flow procedure of exporting models into SolidWorks from photogrammetry software.

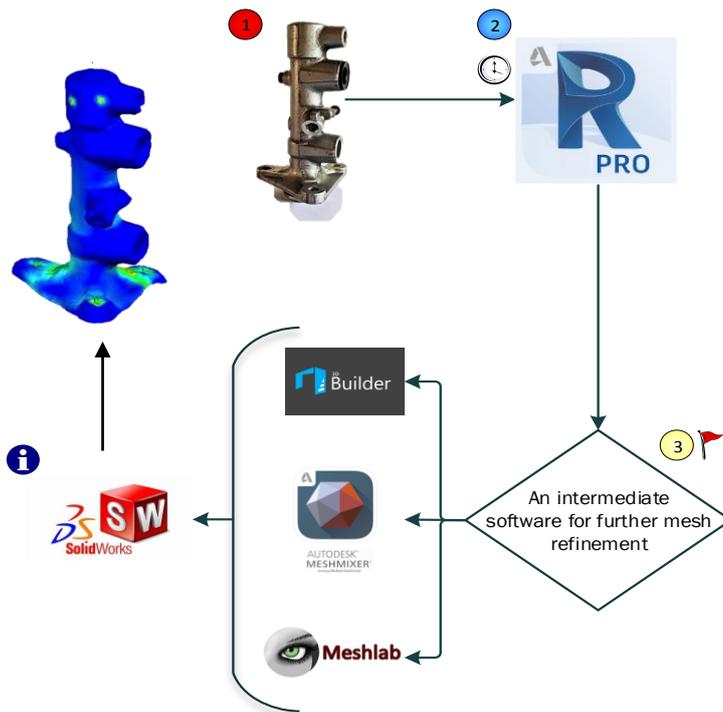
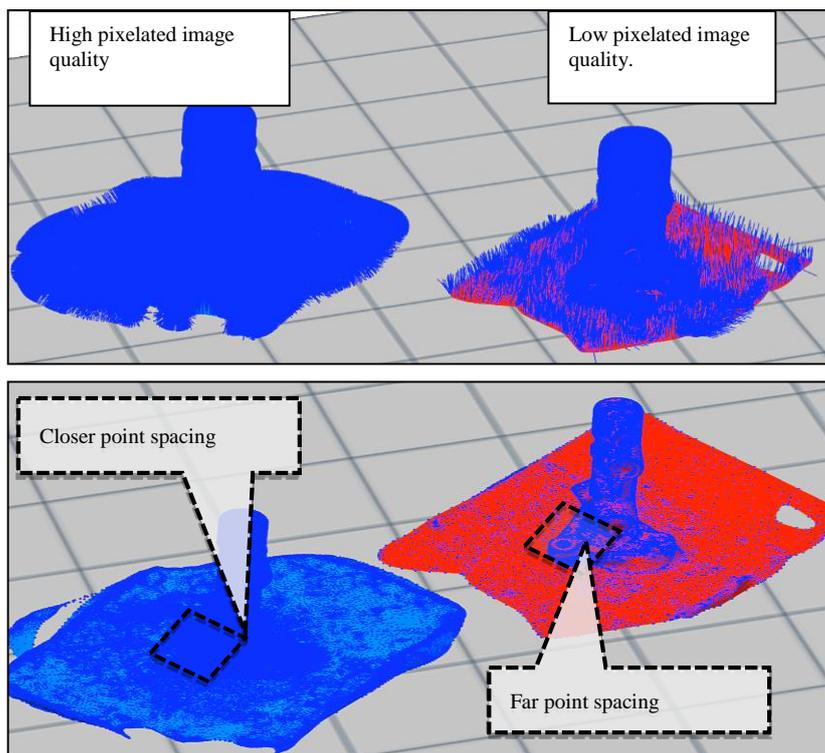


Fig. 7. Pathways in pursuing modeling with SolidWorks.

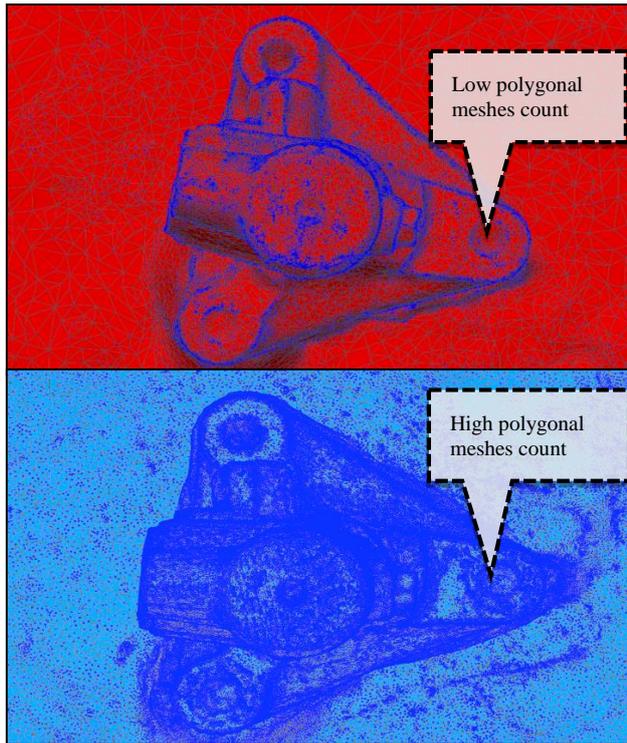
### 3.7. Referencing data and final modelling

Bechet [21] reported that on the basis of validating the peculiarity of the projected photogrammetry shooting strategy for 3D modelling, a criterion is the prerequisite to obtain an extrinsic verification for a precise and certain reconstructed photogrammetric product. Wherefore, point clouds generated in between two 3D entities of different pixelates were carried out to compare the exactness of the visualized geometry model [22]. The subsequent point clouds exhibit higher point density with higher pixelated image quality compared to the other model of lower imaging quality as mentioned previously. Also, point spacing clearly differentiates the detailed texture of a 3D model, whereby the greater the point density the closer the distance between the two neighbouring points in order to acquire all the details for enhance 3D modelling and derivation of new products [23]. Figure 8 depicts the following illustration.



**Fig. 8. Differences in point density generated.**

Herein, higher point density contributes to more polygon faces or meshes count (Fig. 9) that comprises of a larger file in which, lengthens the processing time in SolidWorks for the final modelling procedure, as more memory is required to solve the geometry. Therefore, it is necessary for the 3D model to undergo intermediate software, whereby mesh refinements and reductions are made when importing high-resolution triangulated meshes beforehand exporting to SolidWorks [23, 24].



**Fig. 9. Occupied polygonal faces of different point density.**

#### **4. Conclusions**

The preface of image-based methods demonstrates several of pragmatic outcomes, nevertheless, recognition in images are dependent with the hindsight of photogrammetry in computer graphics development. The photogrammetry techniques have behaved as an enhanced substitution method in the context of photometric modelling procedure. On that account, this research highlights the shooting strategies investigation for digital close-range photogrammetry technique in developing a 3D model. Therefore, prior to the introductory of image-based procedures, the most prevailing course to gaining rectified realism is to comprise deeper in physics philosophy especially into simulation supported rendering approaches.

Fundamentally, image-based platforms are a vitalizing alternative that extracts information from underlying photographic images. However, there are number of limitations in photogrammetry such as photogrammetry is unlikely to render any model that is not captured by the camera. This often refers to the underside of the model, whereby the camera could not photograph its features in that specific region. On the other side, glossy model surfaces and not highly compactible photogrammetry software are the other underlying problem in executing the photogrammetry techniques.

Also, for the present and near future of photogrammetry techniques, photogrammetry has provided several new opportunities in which, are more economical and efficient in future teachings as well as researching works. For

instances, producing a gas plant model in oil and gas industries for tie-in and clash-detection purposes, as a safety-related feature during the maintenance of nuclear power plants stations, vehicles crash-collision detection, documentation in cultural heritage and many more other associated fields that yet to be emerged.

Above all, these collectively of images has encouraged new relations in the computer vision societies towards a refined computer graphics implementation as well as nurturing new perspectives in technology and science in accordance with the Industry 4.0.

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#### Abbreviations

IBM	Image-Based Modelling
IBR	Image-Based Rendering
IMBR	Image-Based Modelling and Rendering
SGM	Semi-Global Matching

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