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# Portable Mini Turntable for Close-Range Photogrammetry: A Preliminary Study

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**Abstract.** Photogrammetry is a science formed of technology exhibiting over a century of historical features and evolution. Moving forward on techniques employed in acquiring data from object portrayed in imaging has refashioned significantly from a pure optic-mechanical literature to an utterly digitize workflow nowadays. Parallel to this, the handling becomes elementary and thus it is practicable for non-photogrammetric naturalist to realize on this practice that the ability to develop 3D modelling from captured 2D photographic images is a noteworthy feature. However, capturing perfect photographic images comprising of all detailed textures and features is a troublesome task. Therefore, in acquiring higher quality and precision modelling, photography procedure techniques are vital to be comprehended. On the other side, an innovative portable mini turntable is planned to be designed as one of the shooting strategies to aid in the photogrammetry process. In this paper, a preliminary study on portable mini turntable development that purposely for close-range photogrammetry is discussed. This study is a part of the design process where several important considerations are identified to ensure the successful of the portable mini turntable development. Based on this study, the future works will be easily executed with a correct justification.

## 1. Introduction

Photogrammetry is an engineering code of practice that has spread by the impact of revolution in computer science [1]. Therefore, the drastic increment in computer utilization has heavily swayed on the photogrammetry application. This can be perceived through a perceptible shift from analog to logical reasoning and digital techniques [2]. The word 'Photogrammetry' is derived from three Greek words, whereby *phot*, *gramma* and *metrein* denote as light, drawing and measurement respectively [3, 4]. Primarily, photogrammetry is the science and technology of acquiring genuine information on surface texture and characteristic. The technique is engineered without subjecting any physical measurement via approaches such as recording, measuring and analysing from the captured photographic picture [5].

The propagation of photogrammetry techniques have become an apparent substitute in image-based modelling approach in consideration of the astonishing creation of pragmatic 3D models on top of its effectual course in communicating both the abstract and substantial idea or better-known as visualization [6]. Additionally, photogrammetry techniques are categorized into two groups of far-range, which branches into aerial and terrestrial techniques and close-range secondly, which this category was the main topic in this study.

*1.1. Photogrammetry data acquisition, procedure and products*
Essentially, there has always been an existing break that defines, as a technological gap between the recent discoveries in research on the other side and the execution of these outcomes in manufactured products that can predominantly lead in an industrial process. Concisely, photogrammetry has become a significant to technological term, whereby several organizations such as American Society for Photogrammetry and Remote Sensing, International Society for Photogrammetry and Remote Sensing and Committee for Documentation of Cultural Heritage (CIPA) are attached in this practice [4]. Notwithstanding on the resemblances between research and development, prominent dissimilarities are portrayed by which the results of photogrammetry studies are not publicly acknowledged yet.

Consequently, research institutes, research departments, universities, and certain mega industries are the only community that exploits the transition to these new emerging digital photogrammetry techniques. On the other side, countless of small and medium-scale industries are not willing to explore on these techniques yet due to self-censorship, micromanagement, inadequacy of expertise in the related field and also most of these such industries preferred on convectional techniques. Therefore, this accord to a time elapsed from the stage of an invention pioneering to a stage of reliable and workable photogrammetry application as illustrated in Figure 1 [2, 7].
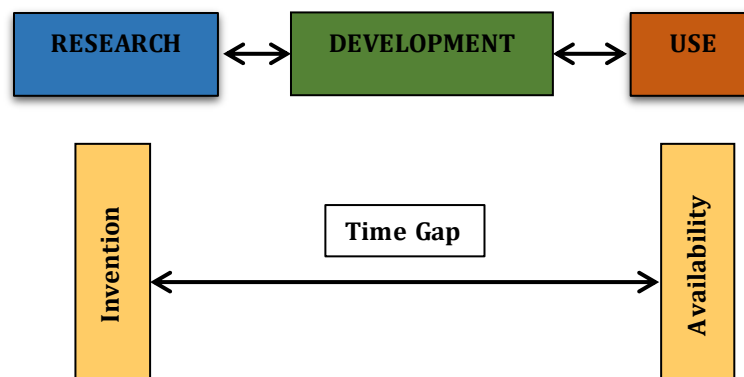


**Figure 1.** Time Elapsed from research pioneering to functional use of a new idea.

Digital close-range photogrammetry represents the principal means of acquiring 3D spatial database of an object from digital images. The utmost distinction between far-range and close-range photogrammetry is in its methodology, specialization and application. In far-range photogrammetry technique it encompasses an area surface ($m^2$) to be covered. Conversely, close-range technique emphasizes on physical object with its features dimensions, which varies between 1 $cm^2$ to 1 $mm^2$ [8]. By far, the abstraction of close-range photogrammetry in this paper is based on utilizing sequence-captured photos to computationally model 3D space. In sequence to comprehend on this subject, a disquisition on intertwined analysis portraying the complexity discipline of photogrammetry is presented, which is called the '*system approach*' as portrays in Table 1 [2]. Fundamentally, the input of this study is acquired via genuine information out of the process of recording electromagnetic radiant energy patterns, mainly of capturing photographic pictures [9]. After, this leads to an output, which is composed of a photogrammetric product outgrowing from several of procedures.

**Table.1** Photogrammetry as in system approach.

| Data acquisitions | Photogrammetric procedure | Photogrammetric product |
|---|---|---|
| | Softcopy workstation. | |
| 1. Physical information. <br> 2. Geometric information. <br> 3. Semantic information. <br> **4.** Temporal information | Dense image matching. (Semi-Global Matching (SGM), Dynamic programming method) <br> ↓ <br> Meshing <br> ↓ <br> Optimizing <br> ↓ <br> Texturing | 1. Photographic products. <br> 2. Maps: <br>    I. Topographic maps. <br>    II. Special maps. <br> 3. Computational results. |

Also, the acquired input is predominantly denoted as physical information. Consequently, the aforementioned data acquisitions practice in contact with the photogrammetric procedure (*black box*) that ensues to the outputs or desirable photogrammetric products [1]. Additionally, this system approach of photogrammetry is further introduced and discussed in section 2.

Today, 3D computer graphics has commenced a tie-up with the photogrammetry techniques in manufacturing technology that assist in the modelling of 3D space acquisition via 2D photographs [10]. Consequently, advancing onto replicating 3D models, as the photogrammetric product via additive manufacturing platforms (3D printing technology) [11]. This medium has gained its popularity due to its practical and applicable method, whereby generated mesh model from photographs can be conceptualized into 3D model via software and desktop computing power. Moreover, the momentary lapse of fieldwork span is an astounding feature and this pre-eminent procedure is elucidated as '*image based modelling*' (IBM) [6, 12]. Therefore, in realizing on this matter several of the common shooting strategies have been a breakthrough. For instance, this includes a high-tech end technique of photo booth with hundreds of cameras, moving a camera around the object or moving the object manually, flying a camera on a drone or an UAV and employing a technique of an automated turntable [13].

### 1.2. State-of-the-art in creating 3D models

In initiating an eminent 3D model from photographs, numerous photographs of the object have to be captured for digitizing [8, 12]. Besides, the captured photos have to envelop every detail of the object prompting to a better percentage of overlapping photos between them [14]. Precisely, about 60% overlap between photographs is advisable to ensure a corrective relative arrangement for processing [15]. A smart phone camera with a minimum image resolution of 8 megapixels is an initial hypothesis in generating the resultant 3D model. Additionally, this study drew a comparison, whereby an image resolution of higher megapixels is featured in another phone model. Technically, higher resolution corresponds to more image detail resulting in precise 3D model.

Therefore, it is anticipated that a shooting strategy for digital close range photogrammetry techniques in a 3D model can be identified and summarized through an investigation from literature. The information in terms of the required parameters and working principle in effective shooting phase of photogrammetry techniques will be referred, as to design a portable mini turntable that will be used as an assistive device during photogrammetry process. Primarily, a mini turntable rotates an object and set increment and triggers a stationary camera [11]. The advantage of a turntable is adapting the object to shoot at all sides thus capturing any every aspect of the object in a full loop [15]. On the other hand, the

camera has to be translated in three different heights and thus making other several loops to acquire higher resolution textures. Additionally, the conceptual design is planned as the camera translation from one point to another, which is to maintain a consistency of the overlapping images captured. Thus, photogrammetry is a measurement friendly, whereby with a high resolution of captured photographs it is likely to generate a 3D model through 3D software and a high level of computing performance. The method is presumed to be much more advantageous compared to the 3D scanning process, where the output is fast, high precision and quality and provide a potential cost solution [16, 17, 18].

## 2. Three dimensional evaluation and reconstruction

The utilization of photographic images in the remake of 3D model acquires various interdependent techniques, as these will be presented in the upcoming subsections. Additionally, this photogrammetry procedure or phenomenon based methodology is called image based modelling (IBM) or photometric modelling [6]. Continuing on the line, these elaborations are the *pre-processing* and *data processing* phases in regard to the fundamental stages of reverse engineering that will be presented in section 3.

### 2.1. Dense image matching

The fabrication of a precise and reasonably pragmatic textured 3D model is practicable. Fundamentally, a dense point cloud is generated, whereby it compels to accomplish a dense pairing between oriented photographic images [19]. On the other hand, referring to the previous statement, conventional techniques are not feasible comparatively. This is due to the dependent correlation of small-scale imagery windows accompanying a one-dimensional epi-polar line that inherit the maximum disparity extent [20]. Aside from that, these modes presumed a persistent variances, whereby displaying inaccuracy at discontinuance regions and tend to obscure the object peripheries [21]. Figure 2 delineates the typical case of 3D point recognition from two images [19, 21].
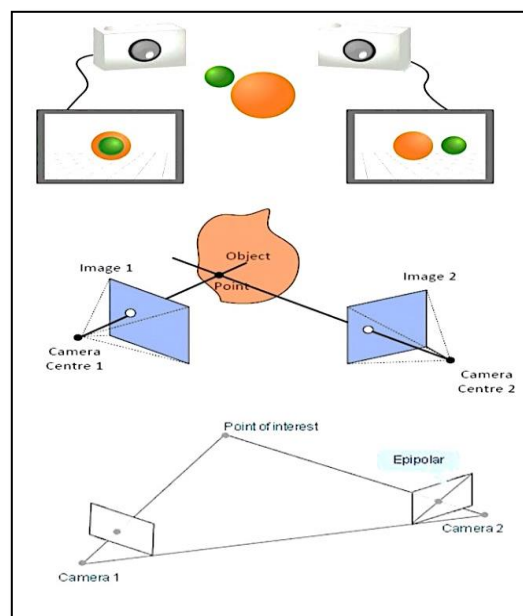


**Figure 2.** The postulation of 3D point recognition from two images.

Alternatively, advanced methodologies in realizing the eminent of dense image matching are being augmented. This progression focuses on acquiring a precise dense stereo matching particularly at object peripheries [21]. Also, emphasizing on the disclosing occlusions and resolving disparities via sub-pixel rendering are the other significant preference objectives. Essentially, there are two noteworthy advanced approaches that have been pioneered in the matching evolution as an optimization predicament, which

are the application of Semi-Global Matching (SGM) and dynamic programming method (DP) [22]. However, the SGM technique is vastly advocated in many computational algorithms and modelling applications and by many researchers in the photogrammetric field considering from its beneficial functions to some degree [23].

The SGM technique plainly utilizes on the concept of pixel-wise matching of local and global stereo approaches at shorter runtime [23]. Thus, yielding a magnificent trade-off between precision and runtime peculiarly at the object boundaries [24]. 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 [18]. In particular, point clouds are the paramount root data initiator for 3D acquisition and thus to acquire a dense point cloud, an analogous point is the prerequisite for practically every pixel in an image [14, 19].

### 2.2. Meshing and texturing

The final sequences in the progression of the 3D geometric model acquisition are meshing and texturing [25]. Primarily, miscellaneous methods are practicable in fashioning an absoluteness 3D mesh model commencing out of a dense point cloud. Hence, these methods can be categorized as in Figure 3.
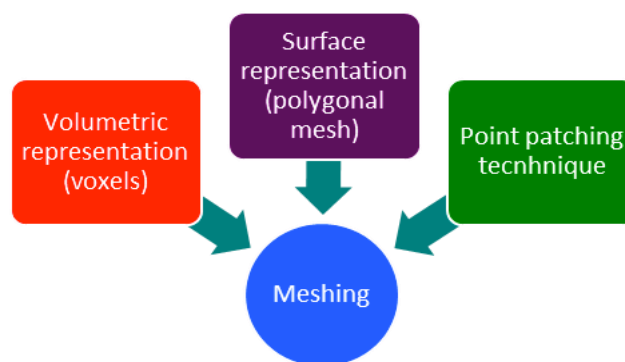


**Figure 3.** Meshing methods.

The volumetric representation by definition utilizes voxel in terms of unit volume factor. It was originated in the beginning of 1970's in the development of medical imaging and nowadays it is conventionally utilized in computer and scientific visualization and also computer graphics. However, the drawback on this point is the necessity for a tremendous storage volume in the meshing process [26]. On the other side, polygonal meshing is a compliant method to definitely portray the outcomes of 3D model valuation on condition that the surface description is adhered [27]. Likewise, point-patching technique is the construction of surfaces and curves directly from the points generated in the cloud [28]. It employs non-uniform rational basis spline (NURBS) mathematical model in fabricating and portraying these parameterized surfaces and curves [29]. After generating a 3D mesh model, texturing is the definitive procedure in which the software outlines digital colour image onto a 3D surface and thus portraying a photorealistic representation [27].

## 3. Extension of photogrammetry: reverse engineering

Reverse Engineering (RE) or better known, as the back engineering is an ageing practice that fashion or develop a digitized computer model from an existing object, whereby it is facilitated via a capable computer-aided engineering that succour in engineering analysis exercise [30]. This conceptualization has become a momentous emerging discipline, whereby being demonstrative on multitude of tasks and researches. Notwithstanding on conventional engineering that reshape the engineering abstraction and model into real framework, in reverse engineering patterns are revolutionize into engineering models and visualization [31]. Also, reverse engineering is a procedure of replicating an existing object in the

absence of any aided drawings. Moreover, this approach defines its availability between systems that acquired interface [32].

Additionally, with the accelerating high-end computer system and computer software, it is plausible to digitally stitch multitudinous photographic images into 3D models virtual representation. Hence, reverse engineering disintegrates and analyses an object in details to disclose essential parameters or concepts, for object modification purposes and to replicate. Above all, reverse engineering is a far ranging in any engineering fields.

## 4. Photogrammetry with a smartphone

The photogrammetry modus operandi gazes at sequence of photographic images as well as reconstructing the camera placements, orientation and lens characteristics for a better images acquisition. Additionally, camera calibration is a major feature for a photogrammetric naturalist, as evaluation and precision is essential for a proper 3D modelling. Wherefore, in the works of better photographic images for prominent photogrammetry upshots via smartphones, several instructions are necessitated as follows.

### 4.1. Lighting environs

For expedient photogrammetry upshots, it is advisable to sidestep from an environment, wherein the light conceives a strong contrast shadows upon the object during photography session. The fact is that shadows are adversaries during the reconstruction period, as this phenomenon decentres the images points in which prompting towards a failed reconstruction model. Thus, essential instructions for proper shooting environments are described further.

a. Shooting interiorly

Experiment the object in a fully closed room with consummate dispersed lighting, which does not create contrast lighting effects or shadowy gestures. Also, abstained from setting flash mode on camera and do not shoot images in a room, whereby curtains are not hung on window panes, as light may penetrates into the room.

b. Shooting exteriorly

Do not experiment the object at midday under strong glazing sun. However, it is prudent to shoot images as early in the forenoon.

### 4.2. Assure that the object is placed at the centre of the camera frame (photo mode), which sates relatively about 70% of the examine object within the full-frame. The prior proportion is achieved via utilizing grid mode feature on camera as, an ideal manner for better acquisition purposes. Thus, the proportionately 70% is estimated to comprise all the nine square grids on the camera with the 5th grid being the most filled and the rest are filled marginally of the examine object.

### 4.3. The captured photographic images have to be persistently sharp thorough the photography session. Consequently, in archiving this promptness the lens's aperture of a smartphone is featured by modes termed as Auto Exposure (AE) and Auto Focus (AF) lock or known as *AE/AF Lock* in which it activates the tone by locking onto the impeccable focus and consistency exposure magnitudes in the photographic images. Thus, the exposure remains invariably balanced during the similar acquisition period. Additionally, AE/AF Lock ensures that the captured photographs are highlighted with every details displayed. Also, high dynamic range or known as *HDR* imaging is activated to aid better acquisition in generating higher dynamic range brightness imaging.

### 4.4. Do not activate the flash mode and plainly tap on the focus feature mode on various scopes within the scenes, as this is to avoid poor acquisition as well as the reconstruction from being blobby Therefore, it is advisable to feature the focus mode at the centre of the 5th grid to where the object is screened mostly as well as portraying balanced lightning intensity from every angle in sequence to acquire the best texture.

*4.5.* Supposing the object is retained statically and only the camera is moved around the object during the photographing session, thus, it is expedient to mount the smartphone on a tripod. Advantageously, the tripod stabilizes the phone and allowing less shakes during the capturing period, as blurry images can be hindered.

*4.6.* On the other side, the exposure scale-level on the camera can be calibrated via focus mode. Herein, a desirable level of exposure for absolute "tack sharp" photographic images is archived.

*4.7.* Do not edit, crop, mask and filter the captured photographic images beforehand advancing into reconstruction phases or utilizing filter smartphone camera frame during the photography session. The point is that these images may bring about failures during the reconstruction period aftermath.

## 5. Preliminary data acquisition and analysis

For preliminary data acquisitions, the most common and accessible shooting strategy is moving the camera around the object. Additionally, for high quality results when shooting objects, the basis idea is to go around the object shooting full loops of images in increments of 5 to 15 degrees.

On the other side, if the object is complex and has lots of occlusions, it is advisable to shoot in smaller increments and to fill in any heavily occluded areas with extra images at the end. Essentially, any surface on the object must be visible in at least two or more photos to be reconstructed in 3D. Besides, fill in as much of the frame possible with the object during the photography session. Furthermore, for larger objects or to acquire higher resolution textures at the end, it is prominent to shoot closer to the object in overlapping rows. Additionally, two phone models with distinct camera lens resolutions of 8 megapixels and 12 megapixels are utilized respectively during the photographing session. Later, these images of dissimilar resolution are then worked with Autodesk Recap for a preliminary 3D reconstruction and the acquired results are portrayed in Figure 4 demonstrating the dissimilarities respectively. In this assay, a clutch master cylinder is utilized, as a model for a preliminary test.
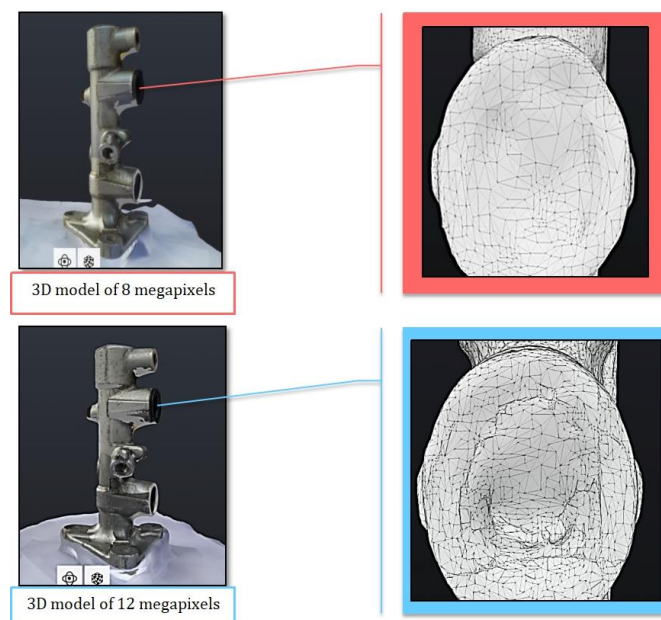


**Figure 4.** Preliminary 3D reconstruction results and analysis.

In Recap, the meshes properties for both 3D models taken from different images resolution are observed. The object shot by a 12 megapixels lens camera has higher number of mesh polygons that the visualizations is sharper compared to when it is shot by the 8 megapixels lens camera. Thus, this

preliminary information describes that the higher a camera resolution the higher the mesh density. However, higher resolution images utilize a longer processing time and in future it may require much more RAM for smooth processing [33].

The contrast portrayed is based upon the photo resolution produced from the both smartphone models, as image resolution is determined by the capabilities of its digital camera. However, the results acquired are fairly satisfied, as the model is processed only with 80 imagines. Thus, the sequential photo redundancy will be enhanced in the upcoming 3D reconstruction through a portable mini turntable approach for a better acquisition [34].

## 6. Furtherance in developing a portable mini turntable

Development of the portable mini turntable can be accomplished through a heedful implementation of an engineering design process, whereby every aspect of characterization as well as specifications are inspected in detail before testing and verification of the product is made. Additionally, the photogrammetry turntable will be tagged, as a Pre-Production Prototype (PPP) for practical purposes that aid in the photogrammetry methodology. Notwithstanding of its appearance, the product design will be developed through a SolidWorks 3D CAD solution that delineates the detail design phase, which aids throughout the photogrammetry shooting strategy. Also, the turntable enigmas are defined initially, whereby its purposes and planning are stressed as well as including benchmarking of several conventional photogrammetry turntables. After inferring on particular instruction of the turntable conceptual design, concept generation is made clear. Additionally, brainstorming is the primary supplement of this stage after functional decomposition. Thus, the progression in developing a photogrammetry turntable is accomplished in line with the proposed workflow as depicted in Figure 5.
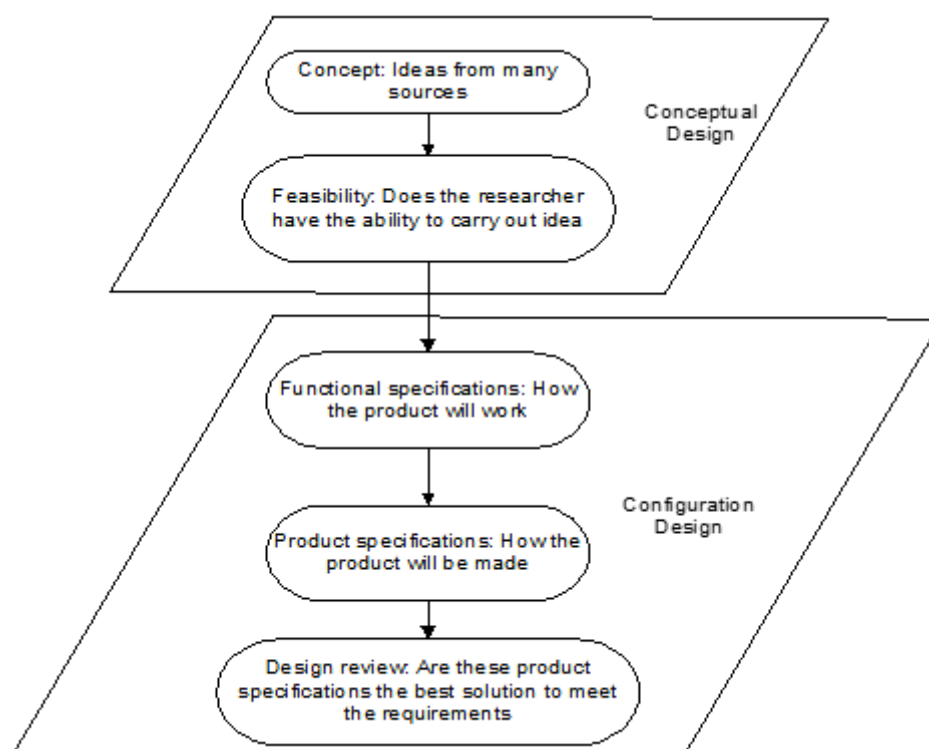


**Figure 5.** The proposed workflow of the fabrication procedure.

## 7. Summary and future works

The new-fangled photogrammetry method transfigures two-dimensional photographic images into three-dimensional spatial model through CAD software. At the same time, reverse engineering approach

is capacitated to acquire the digitization of substantial object inducting form the point cloud [35]. Subsequently, developing a digitized computer model from an existing object, whereby it is facilitated via a capable computer-aided engineering that succour in engineering analysis exercise. Nevertheless, this remarkable venture is often restrain due to the fact of limitations displayed in modern technologies. As the development of a turntable is succeeded, the major data acquisition is pursued with a turntable shooting strategy in accordance to the first objective of this research. A turntable rotates in a set of increments that triggers a stationary camera and the advantage of the turntable is shooting the object at all sides and thus capturing the entire object.

Without a doubt, this *Pre-Production Prototype (PPP)* turntable has to be developed through several potential design alternatives to ensure a suitable design is functionally efficient, easy to use and robust to response to inputs. As a result, embodiment design is the most vital phase in the fundamentals of engineering design study as this preliminary step provides a broad view of the existing design structures. Thus, Table 2 shows the functional factors and alternatives to be considered for the development of the portable mini turntable in this study. Therefore, these selections of criteria on the configuration design alternatives are based upon the consideration of design efficiency, sustainability and its authentic values in a serviceable environment.

**Table.2** Functional factors requirement for the development of prototype turntable.

| Product functional factors | Potential alternatives | | |
| --- | --- | --- | --- |
| | Alternative 1 | Alternative 2 | Alternative 3 |
| Gain energy | Batteries | Power Socket | USB cable |
| Energy conversion | Synchronous motor | Servo motor | Stepper motor |
| Case frame material | Wood | Plastic | Aluminium |
| Phone stand material | Wood | Acrylic tap plastics | Aluminium |
| Power transmission | Gear drive | Direct drive | Rubber belt drive |
| Turn ON/OFF switch | Toggle button | Push button | Switch |
| Enabling rotational motion | Square rotating swivel plate turntable bearing | Revolving swivel plate turntable bearing | Fidget spinner ball bearing |
| Assembly and disassembly | Rivets | Self tapping screw | Wood dowels |
| Type of microcontroller | ArduinoUno (Automatic rotation) | Raspberry Pi3 (Automatic rotation) | Manual rotation |
| Rotation speed | 30 RPM | 20 RPM | 150 RPM |
| Angle of rotation increment | Rotates continously in full loops | 0 to 5 degrees | 15 degrees |
| Arm extension | Fixed at 50 mm | Moves between 75 to 155 mm | Moves between 250 to 1350 mm |
| Dimensions (WxDxH) of the turntable prototype | (412x474 204) mm | (235x235x82) mm | (600x600x200) mm |

| | | | |
|---|---|---|---|
| Overall turntable weight | 3.0 kg | 5.0 kg | 10.0 kg |
| Max. load capacity (centered) for the turntable to rotate smoothly | 3.2 kg | 2.0 kg | 159.0 kg |

## Acknowledgments

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