3D SCANNERS

Selection Criteria for Common Applications

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INTRODUCTION

3D Scanning, also commonly called reverse engineering, is emerging as a viable tool for design and manufacturing applications, and rapid growth is forecasted. While the technology has been available for more than a decade, it is only over the last few years that scanner technology, software capability and system affordability have progressed to the point of being a tool for companies of all types and sizes. So, while the technology is not new, it appears as such to the majority of organizations in industries as diverse as manufacturing, medical and the arts.

With the growing interest in 3D scanning, the need for assistance in qualifying the technology has arisen. Scanners have variables that are unmatched by traditional tools, such as micrometers or CMMs (coordinate measuring machine). When combined with a limited understanding of the technology, this creates a challenge in identifying the key parameters to evaluate when seeking a scanning solution. Service providers and system manufacturers report that a majority of new users place arbitrary demands on the scanning system and output quality. In many cases, these specifications limit the technology selection, force use of expensive systems or impede the use of 3D scanning. For example, vendors frequently receive specifications for ultra-tight tolerances, with no viable justification, when a realistic and useable data accuracy of 0.010 inch is prudent.

The root cause for the improper specification is the lack of information available on 3D scanning. Without guidance on the important factors to consider, it is not surprising that many organizations default to an initial review based on process type (e.g. laser or white light), accuracy and system price.

The purpose of this white paper is to assist in the evaluation of scanning solutions by describing the “typical” requirements for common applications. Although justifiable, concluding that an application’s demands are more stringent should be proceeded by careful considered. There are occasions where an application is more demanding, but these are the exception, not the rule.

The following information addresses the key application criteria as they relate to hardware (e.g. the scanner). Software is a critical component in the process, and it has a major influence on data quality. However, it is a subject that goes beyond the scope of this paper. Likewise, a discussion of quality/inspection applications is omitted. The requirements for inspection are unique, and therefore do not fit within the context of this white paper.

In this white paper, 11 common applications are described, and 7 criteria are documented. To aid and support a 3D scanner evaluation, top criteria for each of the applications are discussed in detail.

APPLICATIONS AND CRITERIA

3D scanning is applied to a diverse range of applications in an equally broad range of industries. In spite of the diversity, there is one commonality—the base application is the acquisition of 3D, digital definitions of physical objects. From this foundation, the unique requirements arise from the intended purpose of the 3D data and the associated demands within an industry. To align requirements with applications, this paper looks at four industries that have been quick to adopt 3D scanning.

- Manufacturing
- Healthcare
- Cultural Heritage
- Arts & Entertainment

Within these industries, the following applications are reviewed.

- Manufacturing
  - Documentation
    - Benchmarking
    - Digital Archival
  - Product Design
    - Aesthetic Design
    - Retrofit & Aftermarket
    - Replication
    - Industrial & Mechanical Design
  - Tool Making
  - Package Design
- Healthcare
  - Medical & Dental Appliances
- Cultural Heritage
  - Historic Preservation
- Arts & Entertainment
  - Graphic Design/3D Visualization

KEY CONCEPTS

When scanning, it is important to identify the state of the desired data.

"As-Designed"

Definition of an object as originally designed. Elimination of variables introduced by manufacturing processes.

"As-Built"

Definition of an object including any variances introduced by the manufacturing process.

"As-Exists"

Definition of any object including variances introduced by manufacturing processes, wear & tear or environmental exposure.

Within each application, there are numerous criteria that may be used in evaluating scanning technology. However, according to experienced users, the following are the most common and most important:

- Accuracy
- Resolution
- Mobility
- Range
- Time
- Ease-of-Use
- Versatility

Omitted from this list is one important factor, price. The cost of a scanner or scanning services cannot be ignored; it is a component of every business decision. However, price should be treated as a secondary criterion to those items listed above.

Applications Described

Manufacturing

- Documentation
  - Benchmarking
    - Competitive analysis to discover a product's design or how it was manufactured. Commonly referred to as reverse engineering. Note that this application focuses on gaining an understanding of a competitor's products and does not necessarily imply the outright copying of another organization's intellectual property.
  - Digital Archival
    - Legacy components: Documentation of aging components for which design data has been lost, CAD data does not exist or the as-built condition differs from the design intent.
    - Digital warehousing: Documentation of parts, fixtures, jigs and tools that are infrequently used. Allows the digital storage and retrieval of the design, for reproduction at a later date, so that the consequences of inventory management are avoided.
- Product Design
  - Aesthetic Design
    - Ergonomics & human factors: Styling for fit to the human shape or motion paths. Commonly begins with a CAD file that is produced as a physical model and is then hand-crafted to incorporate organic or freeform shapes.
    - Styling models: Objects that begin with hand-crafting to incorporate freeform shapes, soft styling lines or organic contours. A common example is a clay model used in automotive styling.
  - Retrofit & Aftermarket
    - Design of components for existing products. Includes accessories and customization of, or replacement parts for, another manufacturer's product. Also includes legacy parts, which are addressed in digital archival.
  - Replication
    - Direct reproduction of an existing object without additional design work. Includes reproduction of enlargements or reductions. 3D data is commonly used as input for machining, rapid prototyping and molding.
  - Industrial & Mechanical Design
    - Similar to replication, but the scanned object is used for additional design work in either industrial design (styling) or mechanical design. Scan data is imported into a 3D CAD application where it becomes the baseline, or reference, for design modification. Often referred to as reverse modeling.
- Tool Making
  - Production of tools, molds and dies for design alteration, repair/refurbishment and replacement of worn tooling.
- Package Design
  - Design and development of product packaging from a physical object. Common applications are bottles and display packaging (blister packs).

Healthcare

- Medical & Dental Appliances
  - Replication of human anatomy for custom manufactured goods or medical aids such as prosthetics, hearing aids, bridges/crowns.
  - Other applications include implants and surgical aids. However, these are commonly addressed with medical CT or MRI scanners.

Cultural Heritage

- Historic Preservation
  - Cataloging, preserving or restoring cultural artifacts such as sculpture, historically significant objects (e.g. liberty bell), structures /architectural ornamentation and archeological finds.

Arts & Entertainment

- Graphic Design/3D Visualization
  - Creation of 3D digital objects for gaming, animation and special effects.
  - Creation of 3D imagery for photorealistic presentations, product simulations and fly-through animations.

Application Criteria

- Accuracy

  The degree to which the scanned data matches the physical object. While accuracy is the commonly used word in the design world, the better choice is uncertainty, a statistical term used in the inspection and quality realms. Uncertainty (aka accuracy) is the deviation band in which there is a high degree of confidence that a measurement will fall. For example, if an object is 1.000 inch long, and the uncertainty is ± 0.005 in., the scanned data can be reasonably expected to fall between 0.095 and 1.005 in.

- Resolution

  The spacing between the sampled points in scanned data. Manufacturers will specify a resolution that is that of the CCD (charge coupled device) or similar data storage element. However, the important factor is the spacing of data points on the physical object. This spacing is dictated by both the CCD and the distance of the object from the focal point of the scanner.

  For a complete data capture, resolution should be ≤ ½ of the size of the smallest feature to be scanned.

  Note: Do not confuse resolution with accuracy. While resolution contributes to overall accuracy, there is no direct correlation.

- Mobility

  Portability of a scanning system, including consideration for set-up time and calibration. Consideration should also be given to the amount of equipment (e.g. computer, tripod), size and weight that will be transported and the method (shipped, carry-on, checked baggage). For large objects or parts that are in service, portability is often a critical factor.

- Range

  Also called field of view (FOV) and depth of field. The minimum and maximum distance of an object from the scanner and the associated *XY* scanning area. If objects exceed the range, stationary scanners will require multiple scans to capture the entire length or width of an object. A closely associated criterion is coverage, which refers to the ability of a scanner to address line-of-sight constraints. Examples include deep channels, narrow holes and undercuts. In general, handheld or arm-mounted scanners over greater coverage.

- Time

  For scanners, there are two components of time: set-up and scanning. Both may be important for any scanning project. Set-up includes the time to mount or position the scanner stably, the time to calibrate the scanner and the time to prepare the object. Scanning time encompasses the duration required to capture all features of an object. Note that since software is not addressed, its time component, which can be substantial, is not discussed.

- Ease-of-Use

  The degree to which an inexperienced employee can prepare and set-up an object for scanning and execute the scanning process. Typically, as ease-of-use increases, the degree of operator control decreases.

  The steps in the scanning process that influence ease-of use are object preparation (surface coating, targeting), scanning and data processing. Processing the scan data can be more involved than either of the other two steps. While a discussion of software data processing is not included, it cannot be ignored. However, one aspect of data processing is often coupled with the scanning hardware, stitching of individual scans. For scanners that capture an *XY* patch with each exposure, the operator will use the software to carefully align and stitch each scan. For handheld scanners that paint an object, or scanners that rotate the object, alignment is virtually eliminated. This eliminates one step in the process, which makes scanning easier for the operator.

- Versatility

  The degree to which a scanner can accommodate a wide variety of objects, in terms of size, complexity and material properties; accommodate a wide variety of operation conditions (environment, ambient light, vibration); and address common scanning challenges (line-of-sight, shadowing, high aspect ratio). The importance of versatility increases when owning multiple scanners is not desired.

KEY APPLICATION CRITERIA

While any and all criteria may play a role in a scanning decision, it is important to focus on the critical factors for success. Secondary factors may then be considered as appropriate. For each of the following applications, the critical factors are discussed, and typical demands are illustrated.

Manufacturing—Documentation

Benchmarking

When benchmarking a product, important criteria include versatility, accuracy, resolution and range.

Versatility takes on a high degree of importance in this application since the range of parts and assemblies are likely to vary widely. For example, if benchmarking a car, areas of interest may range from a small metallic fastener to a plastic bumper to the fit and finish of the sheet metal body components. Also, the scanned object may require that it be captured in a non-ideal environment, such as under bright ambient light. The breadth of component size also makes range an important criterion.

SCANNER REQUIREMENTS

Versatility ●●●

Accuracy ●●●
- **Fine: 0.001 – 0.010 in.**
- **Gen'l: 0.010 – 0.030 in.**

Range ●●●

Resolution ●●
- **Fine: 0.005 – 0.020 in.**
- **Gen'l: 0.030 – 0.100 in.**

●●● Key consideration
●● Secondary or optional consideration

Accuracy is an equally important criterion for benchmarking applications since a precise digital definition is commonly required. However, it is critical that accuracy demands are not overstated. As an inexperienced engineer may specify inappropriately tight design tolerances—that in turn drive up product cost—those with little experience in 3D scanning have a tendency to overstate the needed accuracy of scanned data. For critical design features, benchmarking accuracy will be in the range of 0.001 – 0.010 in., with most features captured at 0.003 in. or greater. However, for all other features, accuracy in the range of 0.010 – 0.030 in. will be suitable. This is true because benchmarking is, in most instances, attempting to capture the intent of a part or assembly instead of specific design information.

Resolution is an important criterion when the focus of the project requires capturing fine details or subtle nuances. If true, a resolution of 0.005 – 0.020 in. is commonly cited. If fine details are not important, resolutions of 0.030 – 0.100 in. will suffice.

Digital Archival

Since digital archival is intended to facilitate remanufacturing an object, both accuracy and resolution are critical factors. Additionally, mobility and versatility often impact scanner selection.

Digital archival demands a data state called as-designed. As opposed to as-built, as-designed requires that the archived data reflects the original design intent and omits any variances created by the manufacturing process. Additionally, the archived data will be used to machine, mold, cast or stamp an object at a later date.

Because of these two conditions, digital archival has the one of the tightest accuracy demands. Typically, this will range from 0.001 – 0.010 in. For precise engineered items, 0.001 – 0.002 in. is a likely scanner specification.

Resolution, which in this application is tightly coupled with accuracy, is also one of the strictest for all applications. For mechanical components or intricate designs, 0.004 – 0.010 in. may be needed. If archiving a freeform shape with little detail, resolution can be adjusted to coarser spacing.

The coverage component of range is important since complete capture of all features is necessary. For mechanical components, there is usually a combination of holes, channels, ribs and undercuts that impede line-of-sight.

Mobility and versatility can also be important criteria. For large objects that cause transportation problems, the scanner will have to be portable to allow in-situ data capture. Portability is also important if an object that is currently in service would reduce plant productivity during the scanning operation. In this instance, downtime can be minimized by having the scanner go to the object. For those that have archival needs for a diverse range of components (e.g. size, reflectivity and complexity), versatility is a key consideration.

SCANNER REQUIREMENTS

Accuracy ●●●
- **Fine: 0.001 – 0.02 in.**
- **Gen'l: 0.001 – 0.010 in.**

Resolution ●●●
- **0.004 – 0.010 in.**

Range ●●●

Mobility ●●

Versatility ●●

Manufacturing—Product Design

Aesthetic Design

For both styling and ergonomic design, the function of the scanner is to capture the form of a hand-worked or hand-sculpted item. In this scenario, accuracy is of lesser importance since the human hand is incapable of producing a model to exacting tolerances. However, resolution is a key criterion because it enables the scanner to capture fine details and soft features incorporated in the object. The two other key factors are ease-of-use and versatility.

Suitable resolution will allow a scanner to capture subtle model features such as textures, highlight lines and soft blends. While this is an important criterion, the required resolution remains a reasonable 0.020 – 0.050 in. for even the most demanding applications. At this level, the scanner will correctly capture details in the 0.040 – 0.100 in. range. If the smallest feature of interest is larger, a coarser resolution will be appropriate.

For this application, it is assumed that scanning is required only occasionally and that the scanner operator is not dedicated to this work. The operator may even be the sculptor of the object. In light of this, ease-of-use becomes significant when evaluating scanners for purchase. Ideally, an object can be placed on any stable surface without preparation; the scanner can be set up with no need for calibration or adjustment of environmental factors

SCANNER REQUIREMENTS

Resolution ●●●
- **Fine: 0.020 – 0.050 in.**
- **Gen'l: 0.050 – 0.100 in.**

Ease-of-Use ●●●

Versatility ●●

(such as ambient light); and the scan is as simple as point-and-shoot. While all of these conditions may not occur simultaneously, it is a reasonable goal for aesthetic design applications.

The sporadic use of scanning also promotes versatility as an important criterion. If used infrequently, it is unlikely that an organization would welcome the purchase of multiple scanners. Therefore, a single scanner should be versatile enough to address most of the potential scanning projects that may arise.

Retrofit & Aftermarket

When fitting a new part onto or into an existing assembly, versatility and mobility are two key considerations. Accuracy and resolution, while important, often become secondary criteria.

The goal of scanning for this application is to capture design data for mating parts and the space in which a new component will fit. In most cases, this means that complete assemblies or products, not individual components, will be scanned. Therefore, versatility is critical. The scanner must be able to capture components made of different materials. For example, if retrofitting an electro-mechanical assembly, 3D data is needed for printed circuit boards, wiring harnesses, plastic enclosures and metal fasteners. Another factor is that the scanner may need to capture information in tight spaces from multiple angles. Often, this demands a operational flexibility of a handheld scanner.

SCANNER REQUIREMENTS

Versatility ●●●

Mobility ●●●

Accuracy ●●● / ●●
- **Fine: 0.002 – 0.010 in.**
- **Gen'l: ≥ 0.030 in.**

Resolution ●●
- **0.030 – 0.050 in.**

Mobility is also critical when retrofitting products that cannot be transported to the scanner. For example, in the aerospace industry, customized aircraft must be scanned in the hanger or on the tarmac. Other examples include equipment for production lines and power generation. If the application is for small to medium objects, mobility is not as critical.

Accuracy requirements depend on what the 3D data is to define. If mounting surfaces and bolt patterns are necessary, tighter accuracy is important. This will require, in generally, 0.002 – 0.010 in. For data that describes the spatial placement of mating and nearby components, a loose accuracy of ≥ 0.030 in. is suitable. For the same reasons, resolution of 0.030 – 0.050 in. is satisfactory.

Replication

The important characteristic for replication is scaling factor. When reproduced at the same or a reduced size, accuracy and resolution are secondary considerations. If replicated as an enlargement, both become critical. Depending on the scanned object, versatility, mobility and ease-of-use may also be key considerations.

When creating an enlargement of an object, accuracy and resolution are critical. If, for example, a 10:1 is desired, accuracy and resolution decease tenfold when the data is scaled. This assumes direct production from the point cloud or STL file without creating a 3D CAD file before enlargement. Although dependent on the scaling factor, a typical accuracy range is 0.0005 – 0.005 in., and a typical range for resolution is 0.004 – 0.010 in.

If creating 1:1 replicas or reductions, tight accuracy and resolution are not required. Depending on the reduction factor, suitable accuracy can be ≥ 0.030 in. and resolution can be coarser than 0.050 in.

When scanning an object with features that impede line-of-sight, coverage (range) is critical. Without complete coverage, CAD design will be required to create hidden features that represent the as-built condition.

Versatility and mobility should be evaluated with consideration of the likely uses of the scanner. Since replication may be used for anatomical parts, organic objects or manufactured goods, there is no "typical" characterization. With a set of potential uses in mind, carefully evaluate the need for scanner versatility and portability.

SCANNER REQUIREMENTS

Accuracy ●●● / ●●
- **Fine: 0.0005 – 0.005 in.**
- **Gen'l: ≥ 0.050 in.**

Resolution ●●● / ●●
- **Fine: 0.004 – 0.010 in.**
- **Gen'l: ≥ 0.050 in.**

Range ●●●

Versatility ●●

Mobility ●●

<u>Industrial & Mechanical Design</u>

In applications where the 3D scan data will be the basis for redesign and modification, accuracy and resolution take precedence. A scanned object will represent the as-built or as-exists condition. From this information, the design intent is determined. To do so, tight tolerance and high resolution are required. In those environments where a technician or specialist will conduct the scanning, all other criteria become secondary. If, on the other hand, the designer will be performing his own scanning, ease-of-use, time and versatility will be additional considerations.

For design applications, the scan data is processed and imported into 3D CAD software. The imported data becomes the baseline, or reference, from which to construct new features or modify elements. Since this data represents the as-built condition, not the design intent, high uncertainty (low accuracy) will lead to inaccurate interpretation of the as-designed state. Additionally, low accuracy decreases the overall value of the scanned data for product design. Even so, the sub-micron accuracies specified by inexperienced users are rarely needed. Realistic accuracy specifications will be between 0.002 and 0.010 in., and with some projects, 0.030 – 0.050 in. is acceptable.

As with accuracy, inexperienced users often arbitrarily specify ultra-fine resolution, which is unnecessary and only serves to swell the size of the point cloud file. Organizations that are experienced in generating scan data for design applications report that a resolution of 0.005 – 0.040 in. is appropriate for most projects.

SCANNER REQUIREMENTS

Accuracy ●●●
- **Fine: 0.002 – 0.010 in.**
- **Gen'l: ≥ 0.030 in.**

Resolution ●●●
- **0.005 - 0.040 in.**

Ease-of-Use ●●

Versatility ●●

Time ●●

Ease-of-use, rapid scanning and versatility combine to make scanning a simple, efficient and accessible process. When the scanner is a tool used by the designer, these characteristics are important. Without them, the designer may opt for other methods that are simpler and more efficient. Speed, ease and versatility eliminate the creation of artificial barriers to the productive use of the 3D scanner.

Manufacturing—Tooling

Tool Making

Tooling inherently demands tight tolerances when used for injection molding, die casting and similar processes. Therefore, accuracy becomes a critical factor when selecting a scanner. In fact, for tool making applications, many organizations will use both a scanner and a CMM to accurately define a core, cavity, cope or drag. The other key criterion is mobility.

Tolerance stacking makes accuracy paramount for tooling making. If machining tooling for repair or replacement, the accuracy of the scanner must be considered in conjunction with the machining tolerance and the tolerance of the molding, casting or stamping operation. If using pattern based methods for forming tooling, the tolerance of the pattern making process and mold casting operation must also be considered. When making tooling for parts with tolerances between 0.001 in. and 0.010 in., desirable scanner accuracy is between 0.0005 and 0.005 in. For molded, cast or stamped parts with looser tolerances, the scanner accuracy may be reduced accordingly.

SCANNER REQUIREMENTS

Accuracy ●●●
- **0.0005 – 0.010 in.**

Mobility ●●●

Unless the tooling is intended for precise, small featured parts, resolution is a secondary consideration.

Mobility is the second key criterion. Due to the size and weight of tooling, it is often impractical to ship it for scanning. Also, if the tool is currently in service, the time for transportation can have significant impact on manufacturing production schedules and product throughput. The ideal situation is to pull the tool, scan it on the manufacturing floor and place it back in service.

Manufacturing—Packaging

Package Design

For proper consideration of criteria, package design applications are segmented into display packaging (e.g. blister packs) and containers (e.g. bottles). While both have key criteria of time and ease-of-use, the demands for accuracy and resolution are much higher for container design.

When scanning an object to develop product packaging, the goal is to capture the gross shape and major features. Therefore, the accuracy can be greater than 0.030 in., and the resolution can be as coarse as 0.050 – 0.100 in. For container design, consumer product companies report a need for accuracy in the 0.002 – 0.010 in. range and a resolution of 0.010 – 0.020 in. However, the source of the scanned object must be considered. If, for example, the scanned part is hand-crafted or hand-worked, looser accuracy may be appropriate. Resolution, however, will remain the same since it is important for the capture of subtle, fine details such as contour lines and textures.

SCANNER REQUIREMENTS

Accuracy ●●● / ●●
- **Fine: 0.002 – 0.010 in.**
- **Gen'l: ≥ 0.030 in.**

Resolution ●●● / ●●
- **Fine: 0.010 – 0.020 in.**
- **Gen'l :0.050 - 0.100 in.**

Ease-of-Use ●●● / ●●

Time ●●● / ●●

Versatility ●●● / ●●

For product packaging, the application takes on the characteristics of aesthetic design. And therefore, ease-of-use, time and versatility become important considerations. Container design, on the other hand, is analogous to industrial and mechanical design, which places greater importance on time than ease-of-use and versatility.

Healthcare

Medical & Dental Appliances

For medical and dental appliances, there are differing sets of criteria that are driven by the application and the mode of operation. For example, if the scanning technology will be used in a lab and operated by a skilled technician, time becomes the key criteria. Since higher productivity yields more profit, scanning time will have a direct impact on the bottom line. Another distinct set of criteria originates from the application of scanning technology to precise dental work for restorations, bridges and implants. While all other medical and dental applications can use loose tolerances, these dental appliances demand the tightest accuracies of any application. For these dental applications, line-to-line precision is desired. This means that accuracies of 0.0005 – 0.001 in. are needed. Fortunately, the size of teeth allows the application of small range, highly precise scanning technology.

SCANNER REQUIREMENTS

Accuracy	●●/●●●
- **Fine: 0.0005 – 0.001 in.**	
- **Gen'l: 0.010 – 0.100 in.**	
Resolution	●●/●●●
- **Fine: 0.002 – 0.005 in.**	
- **Gen'l: 0.030 – 0.100 in.**	
Time	●●● /●●
Ease-of-Use	●●● /●●
Range	●●/●●●

Beyond the above mentioned exceptions, the medical and dental fields have very reasonable requirements that can be addressed by many of the scanning systems on the market. These criteria include time, ease-of-use, range, accuracy and resolution.

Cultural Heritage

Historic Preservation

Preserving, archiving and reproducing cultural artifacts demands accurate representations of the objects, but the accuracy and resolution requirements are far less stringent than those for manufacturing applications. In fact, most, if not all, scanners should be able to provide reasonable data quality for cultural heritage projects. What are more important are time, ease-of-use, range, mobility and versatility.

SCANNER REQUIREMENTS

Time	●●●
Ease-of-Use	●●●
Range	●●●
Mobility	●●●
Versatility	●●●

Time is likely to be the top criterion. Many cultural artifacts will be scanned in the field or on location. For example, a statue on display in a museum will be scanned in the hours after the facility closes to visitors. For those pieces or objects that are removed from display, short scanning time allows the object to be returned in short order. When scanning an object in-situ, mobility is an obvious criterion. The scanner has to go to the artifact, so it must be portable.

In the hands of a museum employee or archeologist, ease-of-use becomes another critical factor. Their roles, and demands on their time, make it unlikely that mastering a technology fits within the work schedule or ranks as high priority. Like the aesthetic design application, an important factor is to have a device that is as simple to use as a digital camera or flat bed scanner.

Range, also called field of view, is important because the size of, and distance to, an object will vary greatly. Documenting a small fossil and a life-size statue will require a broad data capture range. This breadth may be accommodated by moving the scanner, or the object, to capture multiple patches. The other alternative is to use a handheld or arm-mounted scanner that allows the operator to "paint" the object.

Versatility is the final requirement. Varying size of objects combines with a wide variety of materials and scanning environments. Rather than seeking a specialized device, cultural heritage applications are best served by good quality, general purpose scanner.

Arts & Entertainment

Graphic Design

Unlike the manufacturing, medical and cultural heritage applications, the graphic arts are about one thing, visual impact. When creating characters for a game, digital actors for a movie or virtual worlds for simulation, scanning's role is to deliver great looking 3D digital data. For graphic design, accuracy is of little concern (0.100 – 0.250 in. will do for most). What are truly important are ease-of-use, time and versatility. For some projects, resolution may also play an important role, if for example, the texture of a character's skin is important.

In this application, a scanner is an artist's tool that should be readily available and require little training, experience or understanding of how to obtain good data. So, ease-of-use becomes the number one criteria. Analogous to a 2D flatbed scanner, the 3D scanner should be as simple to operate and just as available. Similarly, the scanner should deliver the 3D data rapidly, demanding little time for set-up of the scanner, preparation of the model and scanning of the object. When scanning people, the "exposure" time is also important since movement during scanning will yield unusable data.

SCANNER REQUIREMENTS	
Ease-of-Use	●●●
Time	●●●
Versatility	●●●
Resolution	●●/●●●

Ease, convenience and accessibility are the keys to successful use in graphic design.

Versatility is another factor for success. In this environment, a graphic designer may be scanning people, clay models, organic objects or a multitude of other pieces. With the exception of those who relish new technology, there will be little interest in having a separate scanner for each of these types of scanning projects.

For those times when resolution becomes important, a reasonable request is in the 0.025 – 0.050 in. range. But for most projects, resolution of 0.100 – 0.500 in. will satisfy the demands for creating visually pleasing digital objects.

CONCLUSION

To select the right 3D scanner, prospective users must first identity the intended applications and the intent of the scanned data. This will offer direction in identifying the critical criteria that are needed for successful scanning of objects for manufacturing, healthcare, cultural heritage and arts & entertainment.

With the discussion of 11 applications and their associated criteria, prospective users have a starting point for a description of realistic and reasonable requirements of a 3D scanner. For those applications, or industries, that have not been included in the review, it is possible to discern the requirements by combining the information from those that were discussed and seeking commonality.

With the specification of the true requirements, rather than arbitrarily stringent demands, evaluators of 3D scanning technology are more likely to find a suitable, productive and cost effective solution. Unrealistic specifications will only serve to limit the technology selection, force use of expensive systems or impede the use of scanning technology.

3D scanning is a viable and valuable tool that is being incorporated into companies of all sizes across all industries. With numerous scanners available, there are many alternatives for the acquisition of 3D, digital definitions of physical objects. The right scanning solution is out there; finding it starts with an understanding of applications, criteria and realistic needs.

About the Author

Todd Grimm is president of T. A. Grimm & Associates, Inc., an organization that offers consulting on rapid prototyping and reverse engineering. His experience includes 20 years in the product development industry. In that time, he has held positions in sales, sales management, business management and marketing. He received his Bachelor of Science degree in Mechanical Engineering from Purdue University.

For the past 10 years, Todd has been an advisor for the Society of Manufacturing Engineers' (SME) Rapid Prototyping & Manufacturing conference. He is also founding advisor for SME's 3D Scanning conference. Currently Todd serves as chairman of the 3D Data Capture/Reverse Engineering tech group, and he has been elected to the vice chair position for the Rapid Technologies and Additive Fabrication technical community. Todd is a charter member of ASTM International's committee on standards for 3D Vision systems.

Todd is an editorial advisor for both the North American and European *Time-Compression Technologies* magazines. He is the author of *Users Guide to Rapid Prototyping* and is a frequent contributor to industry publications such as *Design News*, *Desktop Engineering* and *Manufacturing Engineering*.

APPENDIX

Scanner Requirements

Application	Accuracy	Resolution	Mobility	Range	Time Set-Up	Time Scan	Ease-of-Use	Versatility
Manufacturing								
Benchmarking	●●●	●●●	●●	●●	●●	●	●	●●●
Digital Archival	●●●	●●●	●●	●●●	●●	●●	●	●●●
Aesthetic Design	●	●●	●	●	●●	●●	●●●	●●
Retrofit & Aftermarket	●●	●●	●●●	●●	●●	●●	●●	●●●
Replication	●●●	●●●	●●	●	●●	●●	●●	●●●
Ind. & Mech. Design	●●●	●●	●	●●	●	●	●●	●●●
Tool Making	●●●	●●	●●●	●●	●	●	●	●●
Packaging Design	●●●	●●●	●	●●	●●	●●	●●●	●
Healthcare								
Medical & Dental Appl.	●●●	●●●	●	●	●●	●●	●●●	●
Cultural Heritage								
Historic Preservation	●	●●	●●●	●●●	●●●	●●●	●●●	●●
Arts & Entertainment								
Graphic Design	●	●●●	●	●●	●	●●	●●●	●●●

●●● Key Criterion ●● Secondary Criterion ● Consideration

3D Scanners: Selection Criteria. Courtesy of Z Corporation