VEXCEL

Non-Contact 3D Measurement for Construction Verification and Component Inspection

See It.

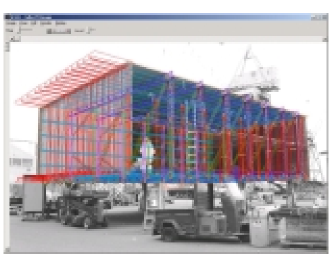
Photograph It.

Measure It.

Introduction

Construction projects often require joining components that have been fabricated separately …sometimes at entirely different locations. Frequently, these components arrive on site where it is discovered that due to manufacturing discrepancies, the components do not come together properly and require field modifications. The costs associated with correcting “mismatched” components depends on the scale of the components and the remoteness of the assembly site, but costs in excess of $200K per day are not uncommon.

Such delays often result in arbitrations or lawsuits to assign blame and costs for the resulting construction cost overruns.



Measurement Solutions

While some manufacturers opt to design components that anticipate and facilitate field modifications, others have instead turned to measurement techniques to verify proper construction of components before they leave the manufacturing site, a more cost-effective solution. A variety of techniques exist for this purpose. In trained hands, each can provide the accuracy required for these inspection tasks.

Manual Measurement

Currently, the most common forms of construction verification and inspection make use of largely manual measurement methods.

In concept, the component is inspected by making a number of “critical dimension” measurements and comparing these measurements to the design documents derived from the CAD (Computer Aided Design) model originally created and used to fabricate the component.

The type of measurements made, and the devices used, are dependent on the scale of the component and the required measurement accuracy. While more precise measurement tools are available for higher accuracy and/or larger scale measurement, plumb bobs and tape measures are the most common manual measurement tools. In skilled hands, these basic tools provide accuracy sufficient for many applications. In less than skilled hands, can mean on-site construction difficulties due to components that are understood to have passed inspection.

In addition to their potentially cost prohibitive nature, manual measurement techniques can be less applicable due to the necessary physical contact.

Other manual measurement techniques include Total Station (survey) measurements of large components and Coordinate Measurement Machine (CMM) measurements, typically used for inspection of small-scale components.

Manual measurement systems include the Total Station (left) and the Coordinate Measurement Machine (right)

Pre-defined “critical dimension” measurements are used to simply spot-check the validity of the component. The number of these measurements used to validate any given component is severely limited by the cost of making the measurements—systems bear price tags of roughly $50K that do not reflect the additional software necessary to manipulate the measurement data, once collected. Adding to this cost is the team of at least two persons most manual measurement methods require.

In addition to their potentially cost prohibitive nature, manual measurement techniques can be less applicable due to the necessary physical contact. Components must be motionless, safe to touch, and completely accessible. To physically measure some components requires shutting down the work area. The result can mean a loss of productivity, which usually translates into profit loss.

Laser Scanner Measurement

Laser scanner systems provide large amounts of 3D range information that can be compared to CAD models for construction verification.

Using this approach, the measurement team:

- Places targets on the component and determines reference dimensions
- Takes laser scans of the component from various viewpoints
- Creates a model of the component from the resulting 3D point clouds
- Imports the measured model into the CAD environment for comparison.

To be effective, laser scanner systems require components to be stable, free of movement or even vibration, and the component surface cannot be absorptive or reflective.

Like manual measurement tools, laser scanner systems are expensive to purchase, generally selling for $150K before adding the cost of software. To be effective, laser scanner systems require components to be stable, free of movement or even vibration, and the component surface cannot be absorptive or reflective. Additionally, these systems are bulky to position in the field, and create problematically large data sets.

Close Range Photogrammetry: Non-Contact Measurement

Close range photogrammetry is a non-contact 3D measurement technique, which makes use of low-cost high-resolution digital images to inspect the whole geometry of a component.

With the advent of low-cost, high-resolution, digital cameras it is now common to document component fabrication photographically.

Close range photogrammetry is a non-contact 3D measurement technique, which makes use of low-cost high-resolution digital images to inspect the whole geometry of a component.

Digital image of fabricated dry-dock wing wall (Courtesy Todd Pacific Shipyards)

Using this approach, a *single* technician:

Close range photogrammetric techniques are unquestionably the simplest, fastest and most cost-effective means of providing construction verification measurements.

- Determines reference dimensions of the component
- Takes photographs of the component from various convenient, and unconstrained, viewpoints
- Creates the photogrammetric database from which measurements are made

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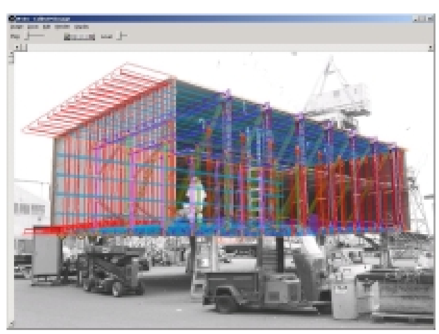
However, not all close range application programs are created equally and many are not well suited for construction verification. The difference? Close range applications that do not interact with the CAD program used to design the component model require two additional steps:

Close range applications that do not interact with the CAD program used to design the component model require additional steps.

- Create a model of the component from the photographs
- Import the measured model into the CAD environment for comparison

These additional steps can mean the difference of days in lieu of the mere hours required by a high-end close range photogrammetry program.

These two additional steps can mean the difference of days in lieu of the mere hours required by a high-end close range photogrammetry program that allows digital images to be directly imported into the CAD environment. From there, the user can overlay the component CAD model onto the digital photograph of the ‘as-built’ component for measurement comparison.



Digital image with CAD model overlay

FotoG™ Photogrammetric Measurement

Vexcel Corporation's high-end close range photogrammetry program, FotoG™, is integrated with typical CAD systems to make the construction verification process quicker and more cost effective than any existing system.

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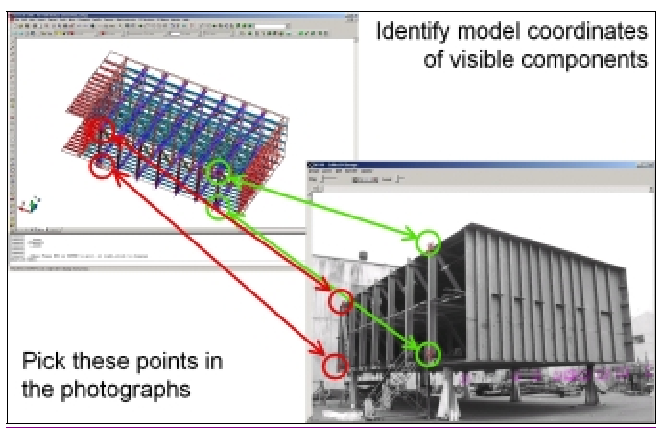
Using FotoG, a *single* technician:

- Determines reference dimensions from the CAD model of the component
- Takes photographs of the component from various convenient, and unconstrained, viewpoints
- and directly examines the CAD model / component photographs for differences.

Each of these steps is a straightforward application of close range photogrammetric techniques and makes use of FotoG's integrated CAD approach.

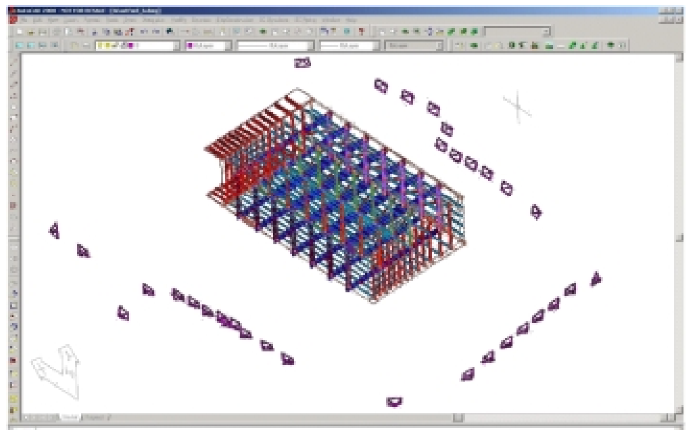
The CAD coordinate system of the component being inspected is integrated with digital photographs by identifying the model coordinates of visible elements in the photographs.



Determining matching reference coordinates

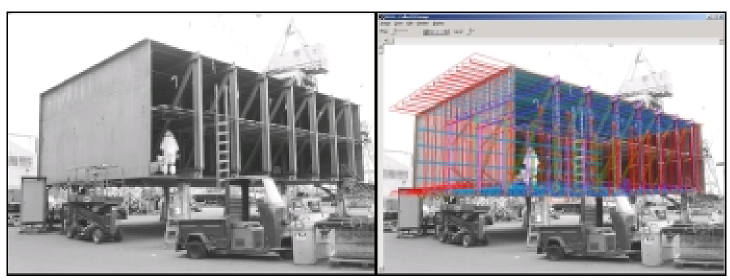
FotoG then automatically generates symbols representing the camera positions for each photograph in the CAD model. The user simply points at a camera in the CAD model to pull up the corresponding image and overlay the CAD model onto the image.

Discrepancies between the CAD model design and the as-built component are instantly apparent to construction verification inspectors.



Calculating camera positions.

Simple visual inspection of these overlay images provides extremely quick identification and documentation of differences between the CAD model and the fabricated component. Discrepancies between the CAD model design and the as-built component are instantly apparent to construction verification inspectors.



The overlay of the CAD model and the digital photograph of the fabricated dry dock wing wall, demonstrate that the upper left connector panels have not yet been attached.

FotoG also provides the inspector the ability to closely examine and document any detail differences between the designed and fabricated component in a zoom mode.

The dry-dock wing wall example used in this document typifies the cost effectiveness of using FotoG for construction verification. FotoG's integrated approach allows a trained technician to complete a project of this nature within two hours—the time it takes to gather the photographs, link them to the CAD model, and create the resulting inspection documentation of the overlay images.

An additional benefit of this advanced non-contact 3D measurement tool is that it can be used to directly modify the CAD design models into true as-built models. Not just identifying and documenting differences, but integrating that information into a truly useful as-built data capture approach.

FotoG is a significant, cost-effective inspection tool for a large variety of industrial production and construction inspection applications.

Conclusion

The system and methodology presented in this paper demonstrates the general capability for construction (and manufacturing) verification / inspection documentation available to users of Vexcel's powerful FotoG product.

FotoG's close-range photogrammetry tools and operational capabilities directly support both the qualitative and quantitative verification of a variety of parts, structures, sub-systems and components. FotoG is a significant, cost-effective inspection tool for a large variety of industrial production and construction inspection applications.

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