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Emerging Technologies in AEC

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BO2365 This class will examine emerging technologies that support the design and construction industry. Technologies we will discuss may include augmented reality, immersive environments, fabrication and prefabrication, mobile computing, 3D printing, and laser scanning..

Learning Objectives

At the end of this class, you will be able to:

- Describe augmented reality and its potential implications in the AEC industry
- Explain immersive environments and the potential implications in the AEC industry
- Describe laser scanning and its potential implications in the AEC industry
- Explain fabrication and its potential implications in the AEC industry

About the Speaker

Jim Balding is a licensed architect with more than 25 years of experience integrating technology into the architectural field. Jim earned his bachelor of environmental design degree from the University of Colorado, Boulder. He has been a member of the Autodesk Revit Architecture Client Advisory Board since its inaugural meeting, and served as the Revit Product Chair for AUGI for five years. He also founded and served as the South Coast Revit Users Group (SCRUG) president for five years. Jim has spoken at several technology conferences and is one of the top-rated speakers at Autodesk University. Jim is currently serving as the Partnership Manager for the Revit Technology Conference – North America as well as the Chairman of the Technology Committee for the US Institute of Building Documentation (USIBD). Jim recently launched his own architectural and design technology firm, The ANT Group.

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Introduction

This class has been developed to give the attendees (and readers) a taste of technologies here now or on the horizon as they apply to the AEC industry. We have attempted to provide background information on each technology, as well as share our experiences with them. This is by no means a complete documentary of all technologies or even all solutions within a category. The technologies fall into one of four categories – Reality Capture, Immersive Environments, Augmented Reality and Digital Fabrication. We have also identified Cloud, Mobile and Robotics as categories and will touch briefly on those during the presentation as time permits.

Reality Capture

Definition

Laser Scanning - *The controlled steering of laser beams followed by a distance measurement at every pointing direction. This method, often called 3D object scanning or 3D laser scanning, is used to rapidly capture shapes of objects, buildings and landscapes*.[i]

Photogrammetry - *Photogrammetry is the practice of determining the geometric properties of objects from photographic images. Photogrammetry is as old as modern photography and can be dated to the mid-nineteenth century.*

In the simplest example, the distance between two points that lie on a plane parallel to the photographic image plane can be determined by measuring their distance on the image, if the scale (s) of the image is known. This is done by multiplying the measured distance by 1/s.

Algorithms for photogrammetry typically express the problem as that of minimizing the sum of the squares of a set of errors. This minimization is known as bundle adjustment and is often performed using the Levenberg–Marquardt algorithm.[ii]

Reality Capture in AEC

Currently the primary use of reality capture in AEC is to document existing conditions. The use of reality capture provides a quick efficient way to digitally capture existing conditions in a meaningful way. Architects and engineers are using this process to give them an accurate starting point for renovation work. Construction companies are using it to verify existing conditions as well as verification during construction to ensure elements have been placed accurately as well as check for construction tolerences.

Additional uses include the accurate modeling of spaces to enable the use of digital fabrication.

Pros

The benefits of capturing existing conditions digitally are speed, accuracy, size and schedule.

Speed – In an open room with few obstructions a point cloud scan can take as few as 3-5 minutes depending on the equipment and resolution.

Accuracy – Point cloud accuracy can be as small as 1/32" or less (not needed or recommended for building documentation). This allows for the design team to begin with the most accurate backgrounds/models ensuring the design will fit and work.

Size – One of the downsides of getting as-built information is the tight spaces people would have to access in order to document them. Laser scan heads are as small as 9.5" x 8" x 4" and 11 lbs.[iii] This form factor allows the scanner to be placed in small cavities to document the space.

Schedule – In traditional as-built documentation it is quite common for the designer or engineer to require more information from the space. With the digitalization of the space, the designer/engineer can access the space online to gather the information they may need, thus eliminating additional visits to the site. In addition to that, the time to create background drawings or models can be reduced with the ability to trace or use the data as a background.

Cons

Depending on your point of view, this process can be considered an expense or an investment. The ANT Group sees it as an investment in efficiencies and quality. There is an investment in time made at the beginning of a project that should also be considered.

What to Watch Out For

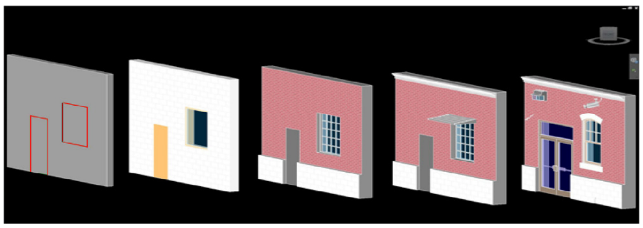
Like all other technologies, there is no "easy button" for scanning a project. You will need to take care to allow for the time required to use reality capture.

Architectural Resource Consultants (http://www.arc-corporate.com/) often presents the "Top 10 Mistakes made when Specifying Scanning".

1. **Not taking the time to define your needs** – You should take the time you need to determine your needs at the end of the game. Do you need the whole building? The interior? The exterior? 2D or 3D?
2. **Not qualifying your service provider** – Care should be taken when hiring a service provider. Be sure to look at their qualifications, abilities and references. (see USIBD below)
3. **Not offering your service provider a job walk** – Job walks can often alleviate any potential issues that may come up during the scanning. This lowers the risks and leads to better pricing and scheduling
4. **Not defining the required control and coordinate system** – Service providers and contractors rely on these control and coordinate systems. It is highly recommended that these are created and maintained throughout the course of the project and building life cycle.
5. **Not specifying the area of interest (AOI)** – a well-defined scope or area of interest is essential in getting accurate pricing and scheduling.
6. **Not specifying the items of interest (IOI)** – When specifying scanning, price and schedule can be reduced if there items that are not important or required for the

documentation. An example might be all piping less than 1" in diameter is not required or all electrical conduit. Remember every item that needs to be documented requires time to process.

7. **Not specifying the level of accuracy (LOA)** – As mentioned above, scanners can be extremely accurate. Using accuracy levels higher than required makes the resulting point cloud denser and therefore heavier and more difficult to work with.
8. **Not specifying the level of detail** – Service providers can provide 2D and 3D data as a result of their scans. The higher the level of detail you require, the more post-processing required the higher the cost.



9. **Not defining ortho vs. real world** – As scanning is capturing existing conditions that are not perfect; walls may not be straight, plumb or at right angles. The design team will need to determine their needs prior to documentation. Traditionally architects prefer orthographic models while contractors prefer real world.
10. **Not involving your service provider** – The scanning service provider is part of the design team and including them in the process reduces errors and improves scheduling when they are "kept in the loop".

Additional Information

There is a new organization based on building documentation – The U.S. Institute of Building Documentation (USIBD). For additional information on scanning and this organization visit www.usibd.org.

Immersive Environments

Definition

Immersion is the state of consciousness where an immersant's awareness of physical self is transformed by being surrounded in an engrossing environment; often artificial, creating a perception of Presence in a non-physical world. The term is widely used for describing partial or complete suspension of disbelief enabling action or reaction to stimulations encountered in a virtual or artistic environment. The degree to which the virtual or artistic environment faithfully reproduces reality determines the degree of suspension of disbelief. The greater the suspension of disbelief, the greater the degree of Presence achieved.[iv]

Immersive environments can take many forms – Cave/iCube, head mounted displays (HMD's), domes, large screens (IMAX). These environments at a minimum capture your peripheral vision but can include sound, smell, temperature, humidity and air pressure or wind. Some people would consider a tablet an immersive tool, perhaps when used as a mobile viewing device in connection with the gyroscopes, accelerometers and internal compass.

Immersive Environments in AEC

The use of immersive environments has many facets and potential facets within the AEC space. There are benefits for the consumer, owner, designer and design team.

Consumer – providing an immersive environment for a consumer or user provides, with ultimate clarity, the proposed space. This level of communication is well beyond floor plans, sections and elevations or even renderings and fly-throughs. The immersant "feels" the space with little to no interpretation required.

Owner – in addition to the visualization level stated above, the owner also has a better understanding of the space giving them the ability to make decisions based on better information. This reduces the time for decisions and rework.

Designer – While many designers can envision the final design in their head, it is rare for them to understand the design as a whole or all the potential design options and their implications on each other. In addition, there are systems that allow for design to happen within the immersive environment giving the designer immediate feedback on the space. See THIS VIDEO for manipulation of a built space or THIS VIDEO for a hypothetical example of immersive design environment (including augmented reality and gestural interfaces).

Design Team – In addition to what is mentioned above, imagine coordination meetings where you have the ability towalk through the proposed space rather than flipping through drawing sheets or navigating a Navisworks or BIM on a flat, 2D screen.

Pros

It is easy to image the benefits of using immersive environments. Communication is the key to reducing errors and schedule overruns. Immersive environments improve communication to a level not yet realized.

Cons

The key to having a good experience in immersive environments is having good models and access to the hardware required. Modeling times can be increased for an additional level of reality. Access to the hardware can be a challenge. While the cost of the equipment is continuing to come down, it is not quite at the point where a most companies have the budget for it. Many of the suppliers and manufacturers will provide their systems on a rental basis.

What to Watch Out For

As mentioned above, additional costs and time are required for creating immersive environments. In addition to that, interoperability of file formats is an issue. Most of the systems do not support the formats generally used by the AEC industry. Many have some compatibility with or have plug-ins for Autodesk® 3D Studio Max®.

Augmented Reality

Definition

Augmented reality (AR) is a live, direct or indirect, view of a physical, real-world environment whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data. As a result, the technology functions by enhancing one's current perception of reality. Augmentation is conventionally in real-time and in semantic context with environmental elements, such as sports scores on TV during a match. With the help of advanced AR technology (e.g. adding computer vision and object recognition) the information about the surrounding real world of the user becomes interactive and digitally manipulable. Artificial information about the environment and its objects can be overlaid on the real world.[v]

Displays can be anything from a laptop or computer screen to head-mounted displays (HMD's), eye glasses, handheld devices like phones and tablets to contact lenses and virtual retinal displays (VRD's)

History

The concept of augmented reality was first mentioned as early as 1901 when L. Frank Baum mentions the idea of an electronic display/spectacles that overlays data onto real life.[vi] Now AR is commonplace on TV. The "1st and 10" system was first broadcast on ESPN, 27 September 1998 and is still in use today[vii]. Now days you may see the first down line, down and distance, the play clock and more right on the field. You may also see full 3D models augmented in as shown below with the tower like frame and stats (NASCAR) in front of the crowd at the Oregon v Stanford football game.

Augmented Reality in AEC

The uses and potential used for AR in the AEC space is virtually limitless. AR is currently being used for space planning and "paper dolling" in site planning at a model scale. Designers are also using the technology to visualize full scale projects in the context of the existing buildings on the real site. This same process is used for visualizing portions of the building in construction.

Additional uses are projected to incorporate systems like Google Glass to overlay data (model and text) for visualization at any phase of design or construction. Imagine the plumbing assembly placed virtually in a building showing the plumber not only where the piping is to be routed, but the specifications, and any other pertinent information.

As mentioned above, the implications to AEC are virtually limitless. AR in AEC is truly a game changer.

Pros

The up side to AR is far and wide. AR is relatively simple to create. Existing models can be used via plug-ins readily available. At this point, detail and "photo-realism" are not heavily relied upon as in the immersive environments as these uses are generally for basic information rather than creating the "feeling" of the space. AR is typically seen as a visualization tool for objects in their entirety. Additional benefits can be gained when breaking down the pieces into bit size bits. When interactive data is added, an additional layer of communication can be realized.

Cons

As with the immersive environment, models will need to exist for the objects required. If none exist they will need to be produced. Additionally, the stability of those models can be a bit tricky. When used with a marker, known as a fiducial[viii] marker, models tend to be more stable. Registration, while better than the geo-spacial techniques, requires that the markers are printed to the appropriate size and located properly within the model and on the site. The marker-less versions rely on GPS or other similar technology to position the object(s). These techniques can vary from 10 – 30 feet which is not an acceptable tolerance for buildings and spaces.

What to Watch Out For

As mentioned several times above, there are no "easy buttons" for these technologies even though they are pretty straight forward. Consistency of modeling and platforms is one concern. The interoperability of file formats has not yet been standardized. Focusing on the final use of the models should be planned for carefully. Testing output during the entire process is also advisable when building AR scenes.

Digital Fabrication

Definition

Digital Modeling and Fabrication is a process that joins architecture with the construction industry through the use of 3D modeling software and CNC machines (plus additive and manipulative methods). These tools allow designers to produce digital materiality, which is something greater than an image on screen, and actually tests the accuracy of the software and computer lines.

Computer milling and fabrication integrate the computer assisted designs with that of the construction industry. In this process, the sequence of operations becomes the critical characteristic in procedure. Architects can propose complex surfaces, where the properties of materials should push the design.[ix]

In layman's terms it is the fabrication of objects, pieces or parts of an assembly direct from computer models without the documentation of the objects. There are three methods of fabrication.

Additive – The additive method utilizes the layering of material one profile over the top of the last. Common uses have traditionally been models such as those created using Stereolithography (SLA), Fused Deposition Modeling (FDM) or PolyJet.[x] There are currently experiments being conducted with site sized "printers" printing concrete to form entire structures including the walls, floors and roofs.

Subtractive – The term CNC[xi] (Computer Numerically Controlled) is often associated with the subtractive where a computer controls a router (or other cutting tool) to cut and/or carve material away to form the desired shape.

Manipulative – Manipulative fabrication is the fabrication of an object by the manipulation of a material, often folding and bending to obtain the desired shape or form. Manipulative fabrication is quite often used in the fabrication of mechanical ducts.

All three of these methods can be used to create virtually any object, piece or part of a building.

Digital Fabrication in AEC

Digital fabrication in the AEC space is in its infancy. Digital fabrication methods have been used for several years for models. Digital fabrication is now beginning to work its way into the production of portions of the building[xii].

Pros

The benefits of using digital fabrication is a long list. Beginning with accuracy, the removal of human interaction during the production reduces the potential for error. Other benefits include, reduced cost, reduced waste, the use of lesser expensive materials. Removing the need for annotation to describe a design, digital fabrication allows for bespoke, complex and Biomimicry designs.

Cons

As with the other technologies listed here, there is no “easy-button” here either. Models will need to be accurate and the adage, “Garbage-in, garbage-out” will be truly evident as there is no human interaction of interpretation between the model and the output.

What to Watch Out For

While digital fabrication is run by machines controlled by computers, it is not perfect. Materials and machines vary as do construction environments. Care should be taken when designing for digital fabrication and it is advisable to test and test often. Keep in mind these objects need to be assembled and installed, plan for assembly sequencing and transportation.

Others

Below are a few more technologies to keep your eye out for as they emerge on the scene.

The Cloud

The “cloud” is all around us. There are several uses for the cloud.

Storage – There are already several applications for storing your data on the cloud. Popular solutions are Dropbox, Autodesk® Buzzsaw®, Box, iCloud, Egnyte and Sugar Sync.

Computation – Using the cloud to compute is becoming more popular. Autodesk solutions include optimization, rendering and analytical tools. As these services become more prevalent, the supply goes up and the price goes down, more and more applications will take advantage of the lesser expensive computation cycles. “One computer for 1,000 seconds or 1,000 computers at 1 second for the same price”. Speed wins.

Virtualization – Not necessarily qualifying for the cloud title, but virtualization, accessing another computer and “driving” it from a distance allows for the shift in power from the desktop to the backend. This allows for multiple people to access more resources from lesser expensive frontends. This can be a localized solution or one at any given distance.

Mobile

Mobile is here and now. There are many companies focusing on going to mobile platforms with full or lite versions of products. With ever increasing bandwidth, access and processing power mobile solutions will only continue to grow.

Robotics

Robotics is commonplace in manufacturing. With advances in digital fabrication, bespoke designs and modeling, watch for advances in robotics to make it all happen efficiently.

Others worth mentioning:[xiii]

(See presentation by Kelly Cone – BO3062 – Emerging Technologies: A Glimpse into a Possible Future)

Here and Now

Estimating, QTO, Fabrication, Pre-Fabrication, Coordination, Scheduling, Bar Codes and RFID, Energy Analysis and Layout…

Next

Socially Aware, Cumulative Design, Computational Fluid Dynamics…

Future

Real Time Rendering, Detailed Time Analysis, Mass Customization, Building Fabrication Process Consolidation, Whole Environmental Simulation…

Looking forward

While no one has the preverbal crystal ball, we are certainly seeing an explosion of technologies. If you look closely at them, they seem revolve around one thing – modeling. As modeling becomes more prevalent, detailed and laced with data these tools will only become more valuable. Combine that with the expense and complication of the buildings we build, these technologies will be ever more required and relied upon. The way we see it, these technologies will not only mature, but will converge as the value proposition increases.

Something to think about…

"If you think it is hard to keep up, try catching up…"

- Jim Balding, The ANT Group

Sources

[i] http://en.wikipedia.org/wiki/Laser_scanning
[ii] http://en.wikipedia.org/wiki/Photogrammetry
[iii] http://www.faro.com/focus/us/features
[iv] http://en.wikipedia.org/wiki/Immersive_environment
[v] http://en.wikipedia.org/wiki/Augmented_reality
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