AS-BUILT POINT CLOUD REVIEW OF A CEILING PLUMBING SYSTEM

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Abstract: This research used a 3D scanner to retrieve the geometric information of finished pipe layout inside ceiling space and used the 3D point clouds to facilitate follow-up building management. The presence of as-built pipes enables the measurement of relative locations between various pipes, pipes and slabs, or pipes and walls. This allows the building contractor to determine if plumbing space should be increased with toleration according to the layout or possible maintenance of pipes and the passing route in the future.

Keywords: 3D scanner, point cloud, plumbing, as-built shop drawings, facility management

1. INTRODUCTION

In building plumbing shop drawings, most require the location of the beginning and the end sections. The route and location of the plumbing always change during work on site (Mokhtar et al. 1998). Building plumbing acts as a resource supplier. It not only supplies base requirements, like a drainage system, power and electric system, HVAC system, and gas system, but also it bears Internet pipes or other special pipes for special needs. Everyone is satisfied if the building can use them normally. Therefore, in the building construction process, the building requirements of the future are considered during plumbing configuration. The configuration requirements consider a user's need for determining location and the pipe openings for future use. In the beginning of planning and design, the architect discusses with users about configuration types and produces design to fit their behavior. During actual construction, how pipes location will match with user requirements is considered.

The location and condition will lead to measured difficultly in building plumbing configuration, and influence the work of record. Building are used for a long time, it is possible that the users will change or its purpose, requirements, and equipment renewal needs so that they do not conform to new user requirements. It must change or renew plumbing to satisfy new requirements. However, required pipe equipment is numerous, and the routes are always different with spatial requirements that are not the same. Therefore, when it needs to renew or maintain plumbing, it must investigate the location and function of present pipes for important plan reference information. When buildings are old, it more difficult to control pipes location and routes. Many pipes are configured in the ceiling, when ones needs to refit the pipes must understand the spatial relationship with other pipes so it can determine how to configure other pipes. In the past, even though there were-built drawings of plumbing, the locations were not correct, which led to deficient configuration plans. The result was that the ceiling plumbing produced much difficulty for interior measurement. This presents a great obstruction to new pipe configuration. Therefore many plumbing configurations using clear pipes or in accordance with site conditions, cannot plan effectively in advance.

Since the record on site cannot adequately show the location of pipes, the result is that as-built drawings are different from the real situation. The long-range 3D scanner satisfies this recording requirement. Because the point cloud has three-dimension characteristics, it can, via point cloud, display completely to the relationship of the pipes that is not limited to traditional two-dimension diagram information.

This research used a 3D scanner to scan the plumbing in a building's ceiling to record the plumbing's real location. When ceiling was being installed, we scanned the ceiling twice, before and after the installation, to record the ceiling location in the building, and to register two different scans, and allow the pipes real location is correctly display. When we confirmed the interior pipe location and surplus space in the ceiling, the plumbing designer can use these spaces to plan and configure plumbing, and create reasonable configuration routes. It will not influence the original function of the building, and maintain the original building shape.

2. APPLICATION OF THE 3D SCANNER ON BUILDING CONSTRUCTION

The usual method of building construction monitoring used photos and video along with text.

However, using the limited two-dimension image display, photo and video only for reference to construction process record cannot be used as a reference for future building maintenance issues. The major reason is that the two-dimension image could be easily be interpreted incorrectly. Recently, many researchers demonstrates how to record real environments in 3D mode, such as using photogrammetry to record construction sites or real building shapes, by creating a 3D model from photo images and record the relation of a real building model and environment (Powers 1996; Heuvel 1998; Dorffner and Forkert 1998).

The 3D laser scanner gives a new choice for traditional measurement or photogrammetry. It uses a laser to produce 3D point cloud information in real time. This research used a 3D scanner (Cyrax 2500) to do long-range scans. It can produce a 999*999 matrix maximum. Its scan tolerance is about 2mm at 50 meters. The point density can be regulated by detail requirements. It can register used targets of multiple scans by Cyclone software. There is no limit for the volume and range of a target object (Shih 2002).

Point cloud can display the shape of a large-size building or scanned body, so it is useful for recording historic buildings or important landmarks such as a large sculpture (Rocchini et al. 2001), urban environment (Zhao and Shibasaki 2001), or analyze construction component problems with a RP machine (Shih and Wang 2002).

This research used a 3D scanner to record building plumbing to produce a point cloud readout. It not only can display a three-dimensional record of the pipes, but also can determine the relation between the pipes and ceiling when the ceiling was installed. It used Cyclone to combine different time point cloud results into a single file. This allows us to understand the status of the ceiling and plumbing by point cloud. Cyclone was used to build a 3D model of the ceiling and plumbing and to install the file into general 3D drawing software to design and plan plumbing configuration. It can use this three-dimensional space to simulate follow-up plumbing design.

3. THE WAY TO RENEW PLUMBING IN AN OLD BUILDING

After a building is finished, times accumulate and the way that it is used constantly changes. For example, equipment can be changed or there is a need to work with the plumbing. The building space follow user's requirement as they change, therefore many spaces and plumbing are not in the original design concept. In order to satisfy new user requirements, it must face space changes to change or regulate plumbing equipment. Now, most buildings are easy to maintains since they used clear pipes during construction. Beside the shaft, most plumbing is configured in the ceiling. So many pipes use a ceiling's interior space. However, a building has so many types and number of pipes, the architect could not coordinate everything before construction. So many plumbing configurations need to coordinate and configure with construction site conditions (Ambrose 1992). Most shop drawings only display the beginning and the end of the plumbing, the actual routes and location are improvised on-site during construction by the workers. On the construction site, there is always a need to change the design of the plumbing configuration (Ai-Momani 2000; Cox et al. 1999). However, most changes in location are not recorded. This means that no one can efficiently maintain the plumbing in the future.

In plumbing, if you wish to increase the number of pipes it is very difficult since the plumbers do not record effectively the location and information of the pipes. This causes difficulties for future maintenance needs. This major reason could be spatial user change plumbing for need by himself. A plumber will not be able to coordinate with building management since no one can understand the configuration of the pipes. This causes much difficulty for management and maintenance personnel. So, if the construction company can record effectively location and information of plumbing, it will let management work conveniently.

When architectural firm plans and designs building plumbing, a technician is assigned to do the actual plumbing design. However, every technician makes the plans independently, which allows pipes conflict to with each other, and influence improvised plumbing configuration on site. Almost all architects face the plumbing coordination problems before construction, and then on the construction site, when there are plumbing conflicts that need to be corrected on site. Although it does not influence use and function, it influences the difference with the original shop drawings. As-built drawings cannot correct for the new plumbing routes, therefore actual pipes locations cannot be confirmed. If the building needs to change its plumbing scheme, it cannot confirm the location of pipes in relation with ceiling surplus space, and just develop another space to configure besides the building. The function is solved, but it will continue to destroy the building surface and normal use behavior.

Ceilings can hide many pipes and large-scale buildings have many types of pipes, whose management is difficult. So most use clear pipes during construction. This increases interior space beauty, ceilings are used to segment plumbing to offer a better aesthetics. Since the ceiling is isolated, it will ignore many hidden problems. Beside some dirt and toys, it is a difficult place to maintain the plumbing. In the past, to fulfill temporary requirements to configure some pipes, building management would hire workers to solve the problem function satisfactorily. But for the plumbing manager, he cannot adequately control pipe changes

and prevent possible maintenance problems. In the past, plumbing shop drawings could not offer correct information to building managers, when they needed to renew or maintain the pipes, so they usually did not know what to do. The only way learn about the plumbing is to begin from the starting point and set up new pipes. This maybe is a quick solution to settle the requirement, but it is not a permanent answer. If plumbing continues to increase, it not only makes building resource bear greater loads, resource management efficiency degrades. It only let plumbing manage transparently, to understand where pipes location and surplus space are located. Pipe maintenance can develop its main action, to help managers to work economically and effectively.

4. USE 3D SCANNER TO RECORD BUILDING PLUMBING

This research used a 3D scanner to scan finished plumbing configuration and ceiling installation, record pipes status and corresponding ceiling locations at that time. The scanned object is an L-shape steel building that is twelve stories above ground and three stories below. There are discourse halls, classrooms, and research rooms. Since the plumbing is complicated in this building, and we had limited time and manpower, the researchers chose to focus on the toilet ceiling and HVAC duct of discourse to scan. The interior must consider scan range, the scanner cannot use one scan to record, it must register multiple scans to be complete (see Figure 1.). Therefore, it must consider the location of the scanner and targets for different scan point clouds to register. Moreover, we want to understand the location of the ceiling in the building by scanning the ceiling when the ceiling was installed. We used Cyclone software to register two different time point clouds, for easy observation of the mutual relationships between the pipes and ceiling.

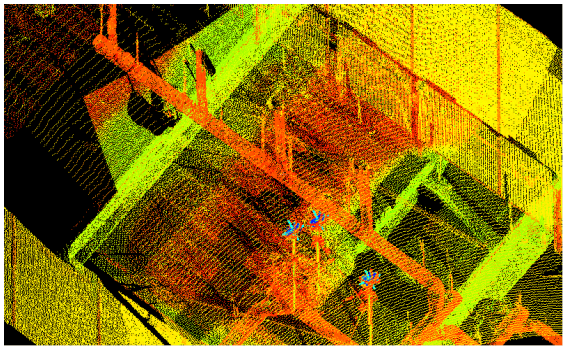

Figure 1. Point cloud of toilet plumbing.

After the 3D scanner records the building's plumbing, it can display plumbing location with point cloud in three-dimensions. Cyclone allows us to rotate, zoom in, zoom out, and define slices, as well as watch and measure the relative location of the pipes in spatial point cloud (see Figure 2.). This allows us to understand quickly the relationship between pipes and ceiling, and via point cloud to control pipes real location and past routes. This information is very important for plumbing maintenance or design. They can use this information to search pipes and plan renewal plumbing projects.

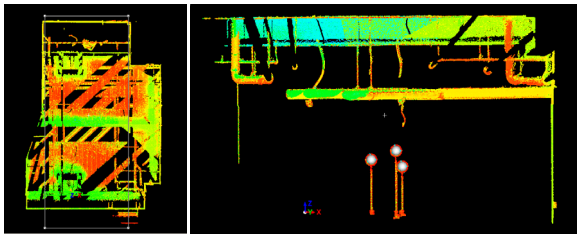

Figure 2. Define slice or fence to watch and measure pipes relative location, left is plan, and right is section of fence.

During the actual building construction, its internal and external scans will follow changes over time. So every time point a scan is recorded is from real information on the site. However, for cases with uninfluenced construction procedures and interference by a construction worker, this study always scans a finished area, such as when toilet-plumbing configuration finished. This team had four people scan a finished area, and record complete plumbing information. When the area ceiling was finished, a wall and slab were done at the same time. We must scan again to record the toilet status, inspect the difference between different times, and register different times point cloud to combine them and determine a basis of the ceiling's internal space.

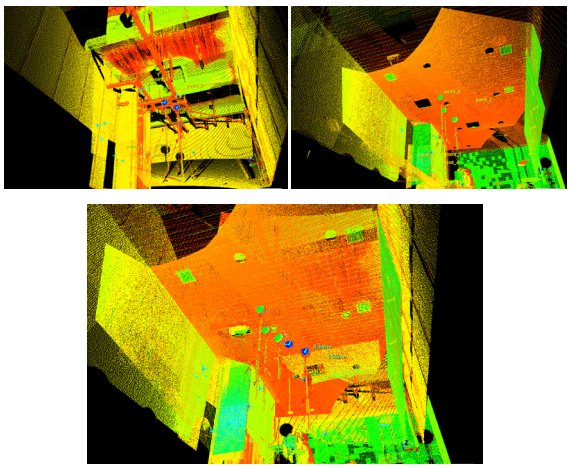

Figure 3. Used different time of toilet scanworlds to register. Top left is first time status, top right is second time to scan, and bottom is registering both scanworlds.

In general, the scan should be done at the same time, because the targets had been set up on site, the location of targets do not change, it will use Cyclone for registering. In different times, the two point cloud scanworlds change due to changes over time to the interior, like increase ceiling, wall finished, and slab

fixed up. Almost everything is covered with the first time scan. So it is hard to find suitable targets to register on different times. This research uses software to calculate ability and determine targets on different time point cloud to set up in the same places which could be different due to the thickness of finished, and some partial pipes from ceiling overhaul openings. It can reluctantly point cloud register. It has some inaccuracy, but the value of inaccuracy is in unacceptable range (see Figure 3.).

5. TO DETERMINE THREE-DIMENSION SPATIAL RELATION IN THE CEILING

After the different time periods are registered and combined with point cloud, Cyclone can observe the relation between the pipes and environment in ceiling. It can watch clearly the location of pipes and corresponding relation between the slab, ceiling, wall, or other pipes (see Figure 4.). So it can measure quickly from point cloud to understand the real location and keep it as well as decrease many possible errors.

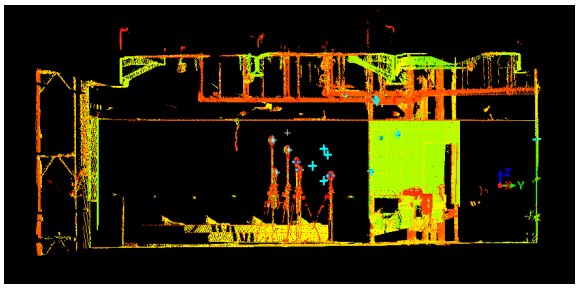

Figure 4. Section of the location of pipes and corresponding relation between the slab, ceiling, wall, and other pipes.

In the past, if someone wanted to measure the spaces in the ceiling it was difficult enough that one almost could not investigate and measure ceiling interiors. This research used scan operations from different times to record the location of the pipes and ceiling. It also used a register to check and inspect ceiling interior spatial requirements. Point cloud format (.imp) was used to transform the data into CAD software acceptable format (.dxf)(see Figure 5.). Next, it proceeds to reveal the environment it is operating in so it can easily find surplus useful space and capacity to offer the plumbing designer.
This study finds much spatial information that can be configured beneficially and possibly create plumbing arrangements that facilitate pipes information control. There is no longer a need to configure ugly pipes outside of a building, but also perform the most appropriate work in the ceiling interior by reaching the purpose of spatial application and the requirements of plumbing management.

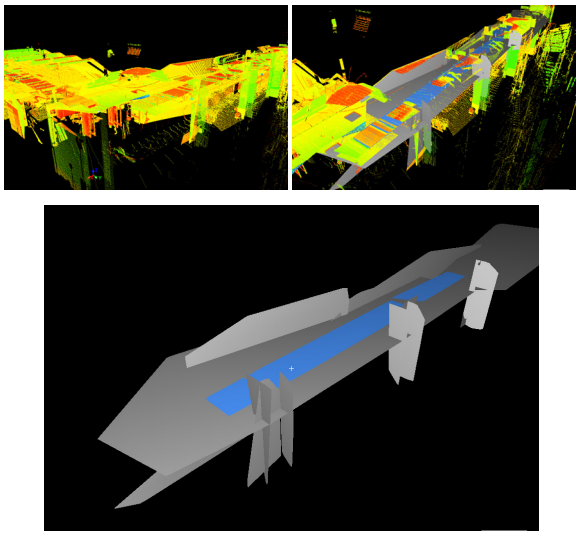

Figure 5. Point cloud transformed into .dxf format to CAD to describe the space in the ceiling. Top left is original point cloud, top right is segment to patch on point cloud; bottom is transformed to .dxf format.

Laser light is used to calculate the real location of the scanned shape, so many backlighted areas cannot display point cloud information. Although it can use targets and multi-scans to decrease vision dead space, the pipes configure better in interior space. It is difficult to scan from top to down, so it will produce some dead spaces. On construction sites, every day has different schedules, so the construction site's contents vary from minute to minute. It is hard to find permanent targets in the construction site, when registering point clouds, one needs to look for landmarks from previous visits and some luck in calculation process. In the final analysis, follow-up point cloud information that has not any been calculated with previous point cloud scans is difficult to register.

6. CONCLUSIONS

This research used different times to record construction in order to discover if it can perform effective point cloud scans in spatial real location, and register ceiling relation status. This information allows the building plumbing or plumbing maintainer to have important referable information regarding spatial changes to reduce equipment or pipes. It can help users understand and determine the location of present plumbing and analyze possible configuration locations in the future. The building interior plumbing arrangement has to be systematic and orderly and not influence follow-up management work.
Since this scanned building is behind schedule, many workers come and go during the construction process, which negatively affects schedule control that will influence scan quality and results. This study almost did not interfere with the workers during the scanning process. But there were still some effect on

the scan rate of progress and contents of the scan.
The area between the plumbing and ceiling space is hard to control in general. This research focused on this problem to offer a method to measure the relationship between the pipes and space in the ceiling. We believe that it can help plumbing designers work in new directions and refer to a basis to plan and make designs with less pipes and less maintenance worries. It will also help the building plumbing manager to manage plumbing and keep the building appearance neat.

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