Advancements in Photogrammetry and Coded Target Technology for Crime Scene Reconstruction

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Abstract: Police investigators and forensic technicians often face challenges in obtaining accurate measurements when documenting crime scenes. Often the scene is in cramped quarters making diagramming difficult. In many cases, it is unfeasible or nearly impossible to 'map' a crime scene with an electronic total station due to unstable flooring, or line-of-sight issues and limits to the size of the room requiring the instrument's setup. Baseline tape measurements are often prone to error for 3-D data, and in many situations the same can be said for producing reliable 2-D data.

In this paper, recent advancements in close-range photogrammetry (CRP) are discussed using color-coded targets for automatic camera orientation and fully automatic measurement. These advancements were developed for forensic 3-D mapping, but many other fields and applications benefit from the sub-millimeter accuracy achieved using standard consumer grade digital cameras and specialized photogrammetric software.

The result of the measurement is then completed through a CAD animation, producing a 3-D "virtual tour" of the home's interior.

1. INTRODUCTION

The aim of crime scene measurement is to reconstruct the real-world incident into a scaled diagram, represented as a 2-D plan-view or a 3-D model used for visualization and animation. Whether final requirements of the measurements are to assist in the determination of a suspect's location, bullet trajectory, blood spatter, weapons location, drugs, or a myriad of other criminal factors, the initial step is to accurately characterize the dimensions of the incident scene. The comprehensiveness of the model required can vary depending upon the use of the 'mapping' data produced. For example, in the case of measuring a crime scene involving bullet trajectory, the bullet path may have traveled through two or more adjacent rooms, and an accurate 3-D model is beneficial in order to document the precise bullet flight path through the rooms. The ability to use non-contact measurement methods is highly attractive when combining the recording of e.g., bullet trajectory, blood spatter, blood pool areas and other bio-hazard conditions - (such as the documentation and recording of meth labs). Conversely, in some crime scenes, a simple measurement of evidence using more traditional measurement approaches may suffice for the needs of the investigator's diagram.

In the case of diagramming rooms in a residential home, apartment buildings, or other interior crime scenes, each environment can present its own unique set of diagramming challenges. No single 'perfect measuring tool' is available that meets all requirements for crime scene recording. The key is to build an affordable measurement 'tool kit', that provides the crime scene investigator effective tools at the scene, ensuring accuracy, that ultimately produces an irrefutable record of the scene through permanent data archival.

2. MEASUREMENT OBJECTIVE

In this example, a simulated crime scene was measured in a four bedroom home. The home consisted of two levels being an upper level and lower level daylight basement. The goal of the diagramming task was to use the automation of coded targets for the home's irregular floor plan. The "irregular" floor plan layout is described as the most difficult portion of the floor to accurately two-dimensionally measure.

The bulk of the floor plan of the upper level was recorded using CRP, while the width and length of rooms were measured by clicking a few vector distances per room using a laser rangefinder. The key to accurately measure the entire floor layout was to "CAD index" the rooms via the photogrammetry targets that modeled the hallways, foyer, kitchen and all door entrances of the home's upper level rooms.

A key advantage of close-range photogrammetry is the level of measurement detail is only limited by the number of images acquired on site. For example, if some of the rooms weren't "visited" by the perpetrator, and are not important to the investigation, the contents of the room(s) can still be "*CRP mapped*" long after-the-fact of the scene investigation, by *only spending time to photograph the rooms* during the time of the scene investigation. Conversely, scene evidence that is obvious during the investigation is highly detailed by either 2- D or 3-D modeling using the photogrammetry technique; be-it using synthetic targets or natural feature point marking in the images.

3. TOOLS USED FOR 3-D MAPPING/DIAGRAMMING

To measure a good portion of the home's floor plan and evidence, a Digital SLR camera was used with the ***iWitnessPRO***^{TM} *(Version 3)* close-range photogrammetry software system along with specialized red coded targets. For the CAD diagram, the CAD Zone's *Crime Zone*^{TM} diagramming software, finalized the work.

Figure 1 is a plan view of the hallways; foyer and kitchen measured using the CRP software system, two photogrammetric scale bars, and Coded Targets, illustrated in the CAD diagram. The area measured with specialized targets is noted by the perimeter of the CAD hardwood floor (center section) illustration.

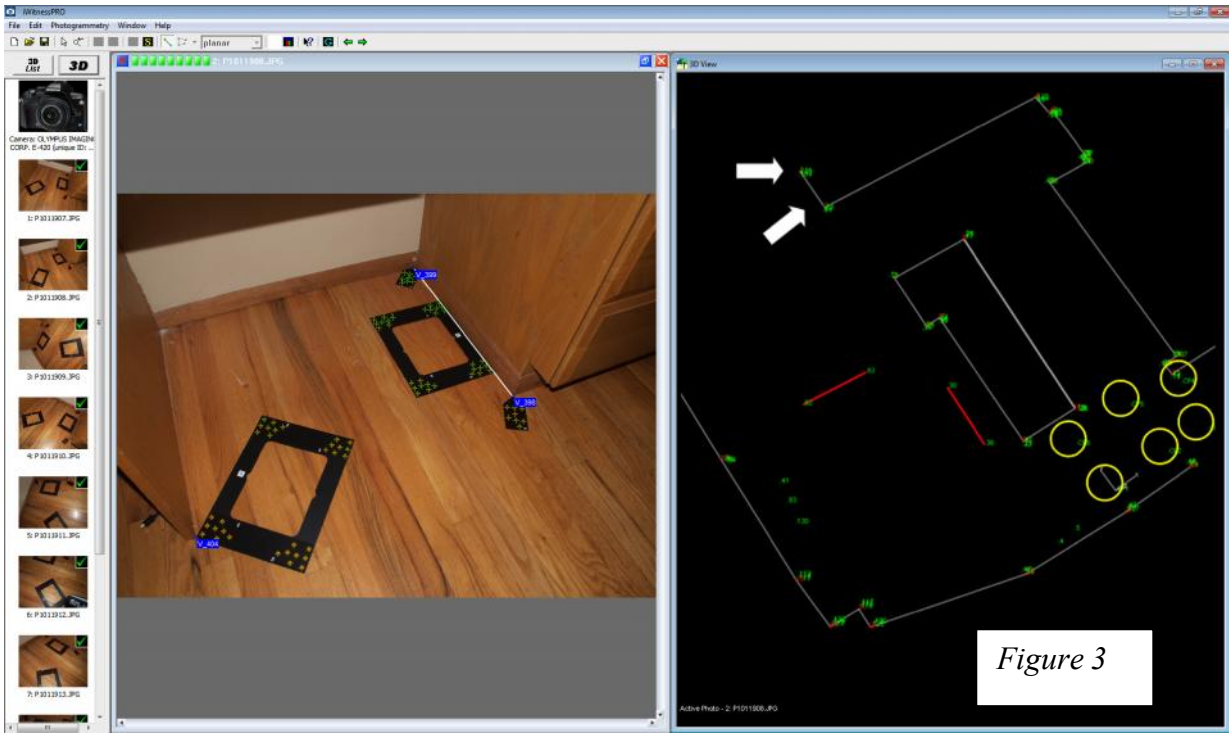
Figure 1 – Hardwood floor corners defined by Triplet Offset Targets

Coded Targets (Code Pointers, Code Frames, and Linker Codes)

Code Pointer Targets facilitate automatic 3-D measurement of untargetable features, where it is impossible to accurately place a single target (such as the right-angled corner of a bench-top, or the curved edge of a kitchen sink). The tip of the code pointer target designates the point of interest, as shown in Figure 2. The code dots are 5.8mm diameter.

Figure 2 –Code Pointer Targets

The camera positions are automatically solved in *iWitnessPRO* by measuring "coded targets" when spatially separated in the images field of view. In order to accurately compute Coded Targets, at least 3 (preferably 4 or more) camera positions should image the Codes from perspective imaging angles. Figure 3 is an expanded view of two Code Pointers, and two Code Frames. Code Frames can be used for measurement or for "fill codes" to ensure the images have enough codes for camera orientation. In this example, the Code Pointers are indexed to the corners of a cabinet counter's base and white-line connected in iWitnessPRO.



Due to the overall size of the project, two CRP networks were "linked" by conducting a least squares coordinate transformation from a half dozen shared Code Linker targets used. The six code linkers were placed in the area of the six yellow circle, noted in Figure 3. These six Code Linkers are shared between two project networks and are automatically "linked" (i.e. a coordinate transformation is conducted in iWitnessPRO V3).

iWitnessPRO V3 permits up to twelve different networks *linked* together into the same coordinate system by using a minimum of four common shared Linker Codes. There are currently a quantity of 133 Linker Codes at the time of iWitnessPRO V3's release, and a total of 981 coded targets. Although it is feasible to accomplish the CRP 3D model in a single network, based on the fact that iWitnessPRO can automatically process several hundred images at a time, it is usually better to limit the individual project networks into more manageable subsets of 150 images or less. This way, the project can be modularized (e.g. a room at a time, and then code-linker "linked" to a hallway and then an adjacent room).

Approximately 35 code frames and 25 code pointer targets were placed on the hardwood flooring of Network 1, shown in Figure 3. Network 2 used approximately 50 of the "recycled codes" from Network 1. It took one person less than an hour to "set codes" and image the entire photogrammetric Network 1 and Network 2. One of the advantages of the Code Frames is they are lightweight and easy to deploy and also removable and recycled from the scene, for hundreds if not thousands of project use's.

The processing time using the iWitnessPRO software and a laptop computer, was about 3 minutes each, for both networks illustrated in Figure 5 to produce all required 3-D points to millimeter accuracy.

The room's walls lengths and widths were simply recorded with a Disto™ Laser Rangefinder, and added to the CAD model, indexed to the doors or entry ways that were CRP measured with iWitnessPRO and coded targets.

The CRP Scale distances are illustrated as two precision scale bars shown as bold red lines in Figure 3, in the 3-D View. The Code Pointers were also line connected in the Figure 3, 3-D graphics view, and prior to DXF exporting from *iWitnessPRO* to the *Crime Zone*.

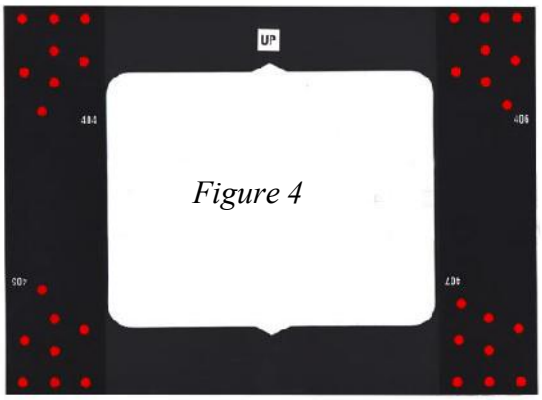


Figure 4

Code frames are precision die cut to dimensions of 11.5" wide x 8.5" height, and .039" thick. They work exceptionally well in "filling the void" in a workspace to ensure there are enough codes for fully automatic measurement. They are typically recycled from one room to the next, if the rooms require extensive evidence gathering or 2D / 3D modeling.

4. EXPORTING THE CRP TO CAD

The photogrammetry software combines all networks into one file for import into any CAD program that reads the DXF file format.

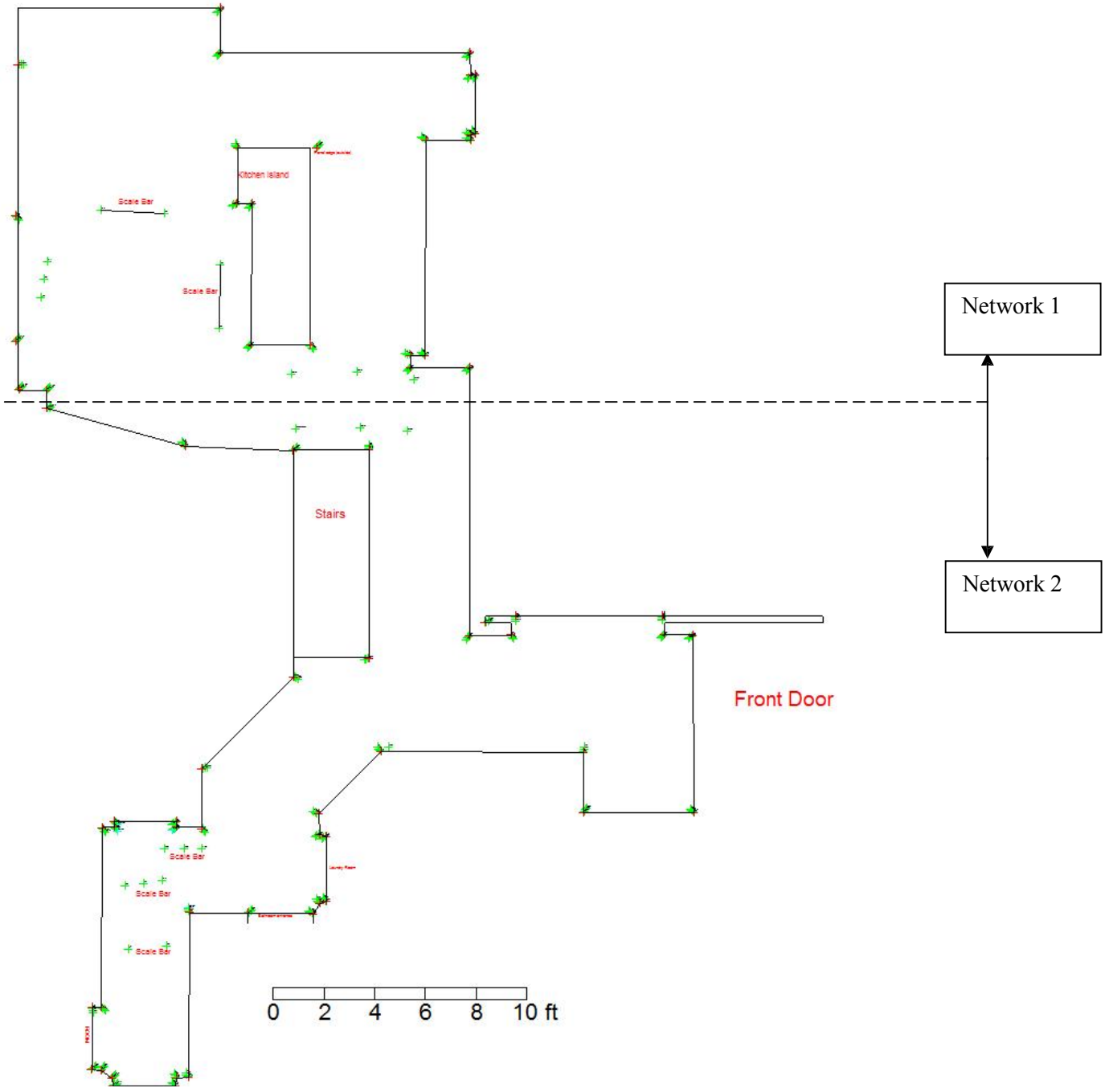


Figure 5 – DXF Export of the Coded Targets in Both Networks

CAD

Depending on litigation requirements, a comprehensive 3-D animation, or a 2-D plan view drawing usually determines how much work is required in CAD through using the 3-D photogrammetry and 1-D laser measurements. Figure 6 is a plan view of the upper level of the home, displayed in the *Crime Zone*.

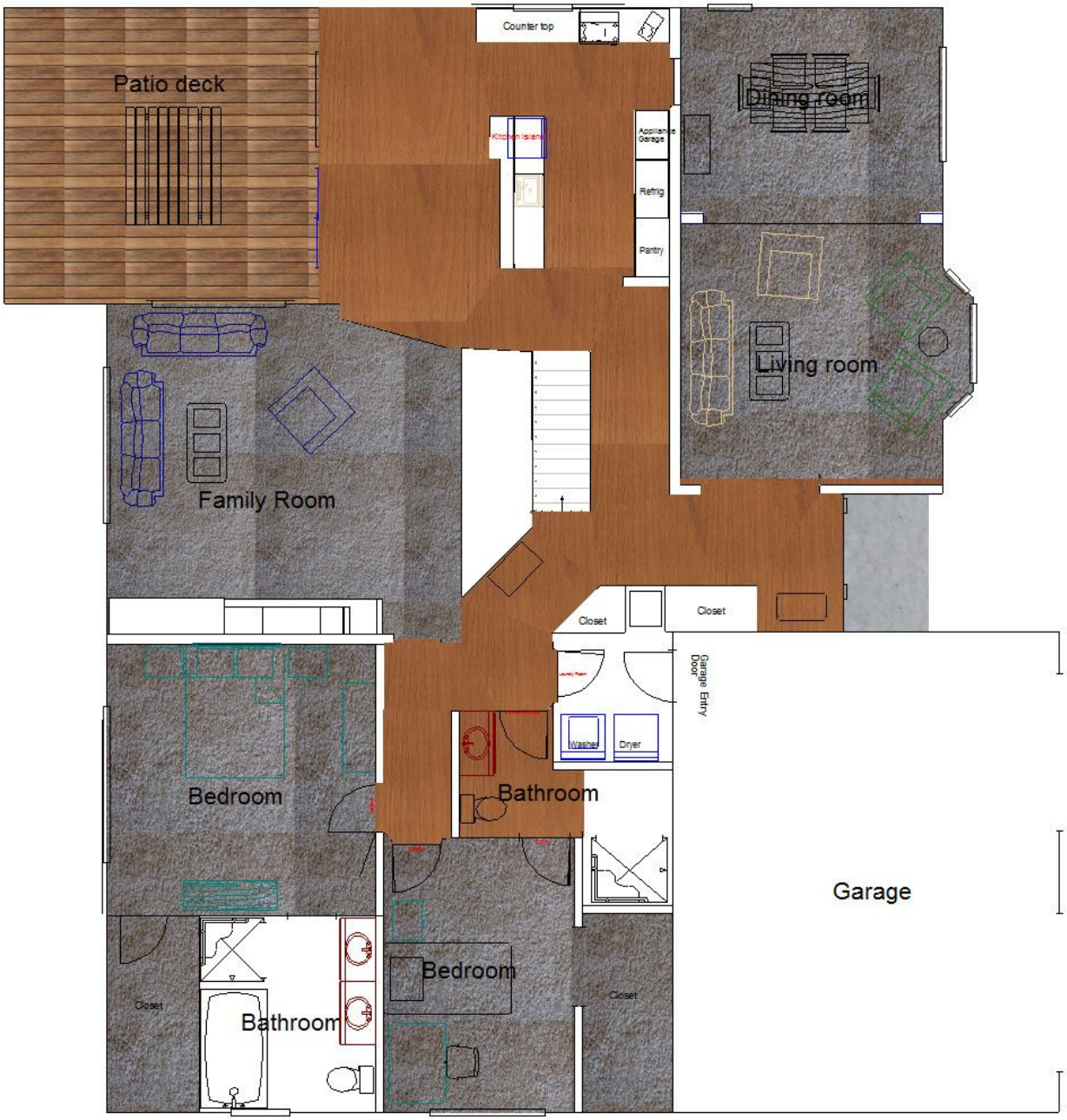


Figure 6 – Photogrammetry and Laser Range Finder measurements illustrated in CAD - Upper Level Plan View

In order to position the two levels of the home, the lower staircase was accurately measured with the iWitnessPRO Codes, "linking" the upper to lower floor levels. The balance of the downstairs rooms and hallway were then measured with the laser rangefinder. Figure 7 illustrates the wireframe of the lower level of the home, presented in CAD.

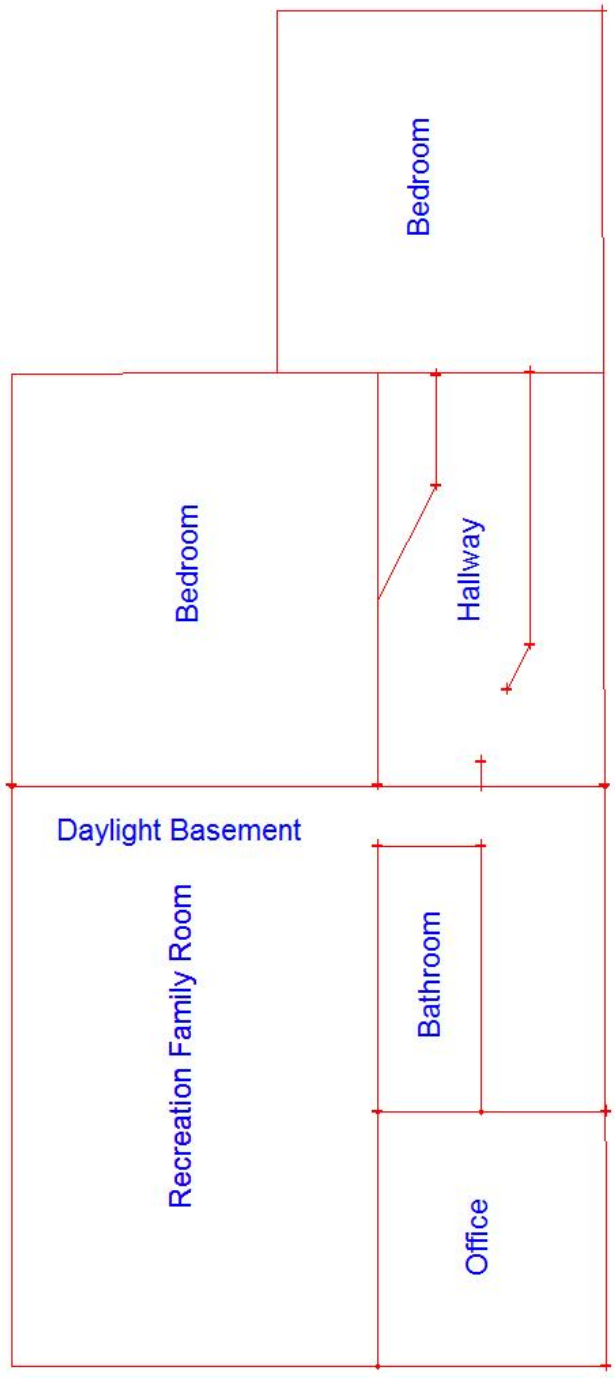
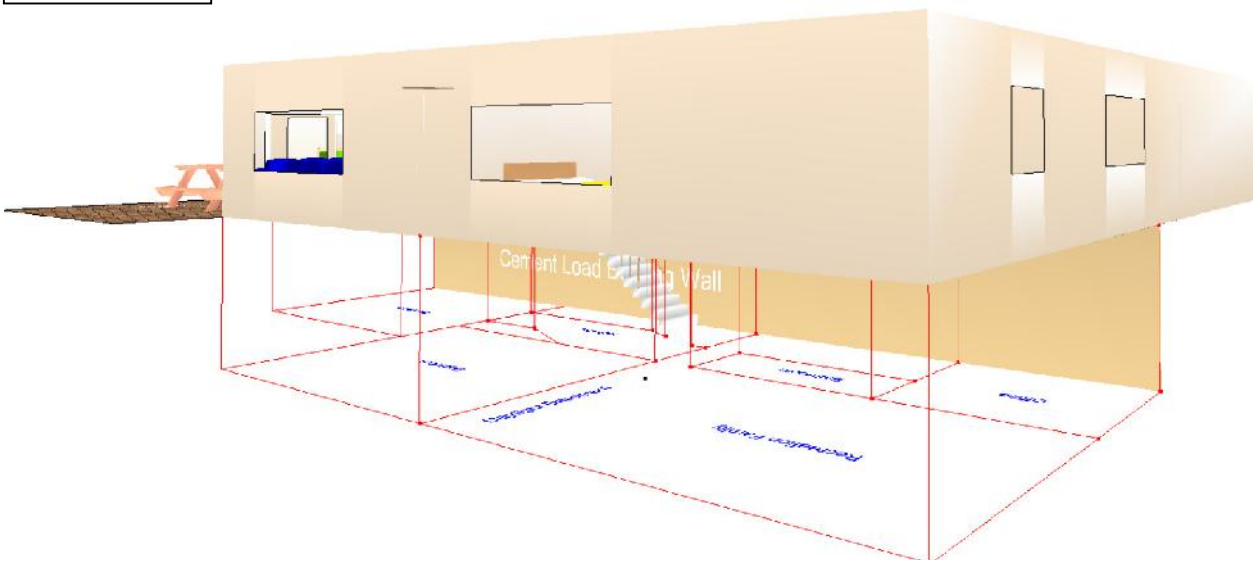


Figure 7 –Laser Rangefinder in a CAD diagram - Lower Level Plan View

Figure 8a and 8b are oblique views of the measured results of the photogrammetry and laser measurements in CAD.

Figure 8a

Figure 8b



Finally, a "walkthrough movie" was created in the *Crime Zone* of the iWitnessPRO measured results. Figure 8 is a screen capture of the interior 3-D model from the walkthrough. The walkthrough movie is presented here: www.iwitnessphoto.com/articles/walk_thru.wmv

Figure 8 – Measurement iWitnessPRO results in Crime Zone

CONCLUDING REMARKS

Close-Range Photogrammetry is widely accepted in law enforcement forensic investigations as an accurate and reliable means of three-dimensional measurement and modeling. The innovation described, incorporating photogrammetric ***Coded Targets*** has been demonstrated to be a fast and an accurate means of 2-D and 3-D data recording for interior crime scene documentation. The laser rangefinder was used in 1-D measurement of rooms. Both the photogrammetry and laser systems complemented each other for use in the CAD diagram, producing an accurate representation of rooms and evidence in a residential home. The combination of image-based measurement via specialized photogrammetric targeting and a moderately priced Digital SLR camera is time efficient on scene at a fraction of the overall cost of more expensive precision metrology systems used for forensic documentation of interior scenes.

