Letter to the Editor

Re: Meline, K. A.; Bruehs, W. E. A Comparison of Reverse Projection and Laser Scanning Photogrammetry. *J. For. Ident.* **2018**, *68* (2), 281–292.

Regarding the above listed article, my concerns fall within three [sic] general categories:

Experimental design.

Problems with citations.

Problems with Experimental Design

An analogue camera was chosen by the authors for their work, but not specified as to make/model. Similarly, a Lorex ECO4 DVR was chosen, but the exact model number is not specified and there are a few models within this product line. The authors do not note any performance testing/validation of this pair and their lack of specificity in the article prevents the reader from repeating their experiment in an attempt to reproduce their results. There is no discussion as to whether this pairing can represent the greater population of CCTV systems.

A legacy Faro Focus 3D S 120 laser scanner was used in conjunction with Faro's Scene software for the laser scanning portion of the authors' work. The scanner created a point cloud of the room as a function separate from the operation of the Camera/DVR's recording of the test subjects. Faro Scene was used to attempt to place single CCTV frames into the point cloud for the measurement exercise.

Faro Scene's current User Manual describes a process for the insertion of images into point clouds in Section 7.5[1]:

There are three ways to use images in SCENE:

- Images can be added with their original resolution to the workspace and thus provide additional information about the scan environment.
- These images are imported into the 3D world into virtual scans with their full resolution. Such images will be interpreted as a high-resolution scan of a plane surface and can be placed on arbitrary positions in the 3D world.

- Images can be used to add color information to already existing scan points.

Section 7.5 goes on to describe the procedures for placing images into the software. Missing from this list is a mention of measuring items in the pictures that are not present in the point cloud.

Section 7.5.1 describes three examples of the use of this functionality: Place of Surface, Place on Plane, and Place in 3D. In the Place in 3D - Measure Points example, the points that are measured are common to both the inserted image and the point cloud.

Figure 7-14 illustrates a procedure for associating points between the inserted image and the scan. Missing from the figure is a measurement of the person depicted in the scanned image. Further to the point, the procedure listed is to measure the associated points, not items missing from the scan.

- 7. Click Associate Points. The mouse pointer changes and is displayed cross shaped.
- 8. Mark at least four suitable scan points in the virtual scan. Try to find scan points in all three dimensions. Each scan point position is listed in the Image column in the dialog.
- 9. Mark the corresponding scan points in the scan. Take care to keep the same order. Each scan point position is listed in the Scan column in the dialog.

In terms of the overall experimental design, the use of the Faro Scene software in the manner described, which is not supported by the manufacturer's guidance, would need to be validated independently of the author's main experiment, or the results of some other validation would need to be cited (see problems with citations).

In approaching the Reverse Projection exercise, the authors note the export of single frames as TIFF images. No discussion is offered as to the encoding of the video frames, and whether the selected frames were I, B, or P frames. Neither was there a discussion as to the quantity/quality of data within the chosen frames or how that was measured.

For the overlay exercise, the authors do not indicate why it was necessary to resize the captured image to match the incoming signal from the camera. Similarly, there's no discussion as to the appropriateness of the interpolation choice versus

other available options (e.g., bicubic vs. nearest neighbor). As to the appropriateness of using a mixing board (and resizing the overlay) versus simply making another recording from the same DVR with height charts in the new scene, the authors do not offer an opinion.

All of this ignores an obvious point, the fitness of Photoshop as a tool for conducting 3D measurements. Is planar geometry, as employed within Photoshop, fit for the purpose of measuring 3D objects in a 3D world, captured in a 2D representation? Does every pixel equal the same real-world distance within the image? Of course not. Photoshop's planar geometry does not account for perspective. Other techniques have been developed in the last 10 years to address this issue, namely Single View Metrology [2]. Yet, again, there is no discussion of why Photoshop was chosen to conduct the overlay exercise.

As regards the sample size calculations for the experiment, the authors do not explain or validate their various sample sizes:

- 1 DVR
- 1 camera
- The paired DVR and Camera
- 1 laser scanner (a legacy model from Faro) and it's software
- 1 location (indoor conference room)
- 40 human subjects
- 2 human examiners performing the Reverse Projection
- 1 human examiner performing the Laser Scanning analysis

A key question becomes, what is being tested? Is it DVR/Camera performance in a Reverse Projection exercise? Certainly not. With only one generic pair, this paper could not be used to inform a wider population of experiments. Is the laser scanner/software being tested? Again, no. The named scanner/software combination is being utilized in a way that has not been validated by the manufacturer or elsewhere for use in this way (see problems with citations). The 40 human subjects recorded by the DVR/Camera? No. The experiment deals with the analysis results of three human examiners.

Thus, the experiment becomes a human performance evaluation and not an examination of the underlying measurement science. As such, it should follow the acceptable rules for the

testing of human subjects regarding sample size calculation. Is a sample of one or two analysts acceptable for such an experiment? What does such a low sample size mean for the interpretation of their results?

The simplest test of performance is a generic binomial test, accurate or not accurate. The next step would be to add controls and move to more complicated tests. But in this case, assuming the simplest test, the sample size is calculated thus:

Exact - *Generic binomial test*

Analysis: A priori: Compute required sample size

Input:	Tail(s)	=	One
	Proportion p2	=	0.8
	α err prob	=	0.05
	Power (1-β err prob)	=	0.95
	Proportion p1	=	0.5
Output:	Lower critical N	=	19.0000000
	Upper critical N	=	19.0000000
	Total sample size	=	28
	Actual power	=	0.9609293
	Actual α	=	0.0435793

As Figure 1 illustrates, at an examiner sample size of 10, the accuracy of the results near that of a coin flip. At 1 or 2, a coin flip is likely more accurate.

Finally, it appears that each examiner was allowed one attempt to calculate the height of the unknown subject. Given the lack of validity elsewhere in the experiment, some attempt at a test/re-test validity calculation should have been undertaken. Haber and Haber [3] speak to this issue of examiner error and test/re-test validity in their work.

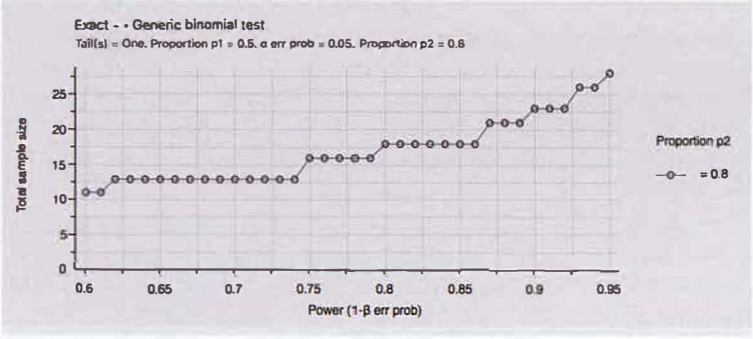

Figure 1
Sample Size - generic binomial test

Problems with Citations

There are many problems with the citations and their relation to their associated statements.

On pg. 289, "Whether it can be and has been tested: Both methods have been tested previously [9, 12, 13], and this study demonstrates, on a small scale, that the results from competently trained examiners would yield similar results..." The statement, "Both methods have been tested previously," is inaccurate. The cited references contain no evidence of such testing. Given the lack of tests or results in the above listed references, the statement, "the results from competently trained examiners would yield similar results" cannot logically be included.

If the authors are aware of a study or studies that are publicly available and that validate the use of the legacy Faro Focus 3D S 120 scanner and Faro's Scene software for a mixed-methods experiment, they should cite them.

Page 286 contains the following statement, "The FBI's standard operating procedure for the RPP method of subject height determination..." The reference list does not contain an entry for the FBI's standard operating procedure. The FBI's SOP was not found via Google search. Without the ability to verify the reference, the statement should be removed, and the actual procedure inserted in its place.

If the authors are aware of a study or studies that are publicly available and that validate the use of Reverse Projection in the manor described in the paper, they should cite them in the appropriate locations within the paper.

Page 289 contains the following statement, "Whether the theory or technique that is employed by the expert is generally accepted in the scientific community..." followed by "Examples of close-range photogrammetry can be found dating to at least 1978 [8]." Reference 8 contains no specific page number that would help the reader to know if this reference, in fact, informs the discussion.

Furthermore, the page contains the following statement, "Whether it has been subjected to peer review or publication:" followed by "Multiple publications outline the evaluation of both techniques [9-15]."

An Evaluation of the Cited References

- Reference 9, *Imaging Sciences in Forensics and Criminology*, is from 2002 and is not a validation study of the technology or technique that is the focus of the paper, but is instead a general overview of the science.
- Reference 10 - Johnson, M.; Liscio, E., *Suspect Height Estimation Using the Faro Focus3D Laser Scanner*, J. For. Sci. 2015, 60 (6), 1582-1588, notes that "very little research has been devoted to investigating the ability of laser scanning technology to accurately measure height from surveillance video..." seems to directly refute the author's assertions. Additionally, page 1582 of the referenced document states, "At present, there has not yet been a published study that has examined the effectiveness of a laser scanning technique to estimate height from video footage..."

The referenced work, a Technical Note in the Journal of Forensic Science, designs an experiment involving images taken by a Canon PowerShot S100 camera, not a DVR or CCTV system. The environment, a residential living room, is noted as an "ideal" environment.

Limitations of the study were noted thusly, "The collection of the known height estimate is a very important part of suspect height estimation. If the known height estimate is incorrect, then the subsequent height estimations will be inaccurate." In the justice system, all subject heights will be unknown. Thus, this paper and the listed technique cannot be accurately used in the justice system unless proven otherwise. If the authors have such a study, then it should be cited. Finally, the authors declare the results of this limited experi-

ment a success but call for further research. "As these issues and others arise, validation studies will need to be carried out in order to bring more reliability and accuracy to the field of suspect height estimation."

- Reference 11, *A Primer on 3D Scanning in Forensics: Part 2*, is from 2009 and is not a validation study of the mixed methods approach of capturing a still CCTV frame and placing it within a laser scanned point cloud. Instead, the article contains an overview of laser scanning technology that references only Wikipedia's entry on laser safety.
- Reference 12, *Handbook of Digital Forensics of Multimedia Data and Devices*, is a Wiley textbook from 2015. The authors, in considering the referenced chapter on Photogrammetry, note, "...Several methods of photogrammetry are available but validation of the result is recommended especially if the result is used in court. Validation is usually case dependent, so validation experiments have to be set up for each specific case. For this kind of validation, a statistical approach is described. New techniques can be adopted relatively quickly as long as the validation experiment is set up correctly." It seems that Chart 1 may be informed by Reference 12, but the authors do not include a validation of the results in the manor recommended by the referenced work.

Additionally, in Section 5.3 of the reference, the reference's authors note, "The 'reconstruction' at the crime scene means making reference recordings of a known similar event under the same conditions using the same recording equipment and settings as was used for the questioned images. In this way the reference images will have the same resolution, compression and lens distortion as the questioned images and from the reference images the ground truth is known." This paper does not follow this guidance given the use of the switcher and the free-form resizing in Photoshop.

- Reference 13 is from a 1989 text, *Non-topographic Photogrammetry*, 2nd ed. I'm not sure how this 1989 text informs the study as Photoshop was in beta until 1990. It certainly can't speak to the mixing of CCTV frames and laser scanned point clouds.
- Reference 14, *Body Height Measurements in Images*, is from 2009 and addressed how differences in camera choice/use can affect the accuracy of measurement results. The authors note, "Reproducibility of measure-

ments per image appears to be strongly dependent on the camera (quality), whereas systematic bias differs with the view point of the camera. Operator dependency of the measurement process is found, so its repetition by different operators is recommended." Repetition of the measurement exercise by different operators was not a feature of the Meline/Bruehs study.

- Reference 15, *Comparison of the Performance of Two Methods for Height Estimation*, is from 2010 and is a case study comparing the results of measurement exercises performed using projective geometry and 3D modeling. The authors note that in their limited case study, projective geometry was the less accurate method and that their results underline the importance of performing validation experiments in casework.

The listed citations should directly support/inform the statement to which they are attached. In the above listed items, the citations do not perform this function and in some cases actually refute the assertions.

Conclusion

I thank you for your time in considering my concerns with the experimental design and citations within the above referenced *JFI* article.

Jim Hoerricks, PhD
Research Director - IRB Supervisor
Towcester Abbey Praeceptory
Castaic, CA

References

1. Faro Scene User Manual. https://knowledge.faro.com/Software/FARO_SCENE/SCENE/User_Manual_for_SCENE?mt-learningpath=scene_downloads.
2. Criminisi, et. al. (2009) Single View Metrology. https://www.cs.cmu.edu/~ph/869/papers/Criminisi99.pdf
3. Haber, L.; Haber, R. N. (2009). Challenges to Fingerprints. Tucson, Ariz: Lawyers & Judges).