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Using 3D Laser Scanning Technology to Create Digital Models of Hailstones

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Insurance Institute for Business & Home Safety

MOTIVATION

- Explore use of 3D laser scanning technology in atmospheric science field research
- Examine in detail the characteristics of hailstone shapes
- Radar scattering calculations for hailstones
- Hailstone density & strength relationships
- Hailstone aerodynamics
- Laboratory material impact testing

SCANNER CAPABILITIES

The HandySCAN EXAscan system applies an active laser and passive photogrammetric components to capture point-cloud data to produce the digitized 3D model. At each data point, the distance and angle from the object to the system is recorded in a scanner-relative coordinate system (Fig. 1). The point-cloud data is connected by applying a non-uniform rational basis (NURB) spline fit. The result is faceted polygons (typically triangles) which produces the 3D surface (Fig. 2). .

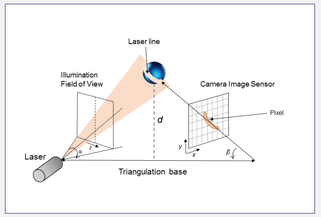

Figure 1. Conceptual diagram of the active laser and passive photogrammetric method employed by a hand-held laser scanner. In this diagram, only one camera is shown, while operational systems use multiple cameras to track the projected laser across the target object.

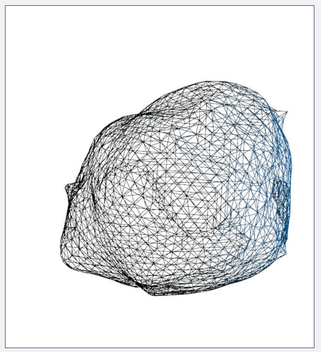

Figure 2. Faceted polygon mesh created from 3D scanner point-cloud data of the first hailstone to be 3D scanned (2015). The surfaces are generated through the operating software using a non-uniform rational basis spline fit.

Unit Characteristics

HandySCAN EXAscan™
Creaform Inc.

Scanner operation: Hand-held, Active laser and passive photogrammetric

Resolution: User selectable, maximum of 0.008 cm

Accuracy: ±0.004 cm

Image sampling: 25 kHz

Data capture: Software-driven, VxElements. Laptop tethered

Data format: .STL

SCANNING HAILSTONES IN THE FIELD

- Hailstones are collected following the passage of a target thunderstorm and are measured and photographed prior to scanning
- Hailstones are coated with a fine powder (i.e. athlete's foot spray) to reduce scattering of the projected laser
- Custom mount was made to support target hailstones (Fig. 3)
- Position targets are scanned and stored by the operating software to define the coordinate system (Fig. 3 & Fig. 4)

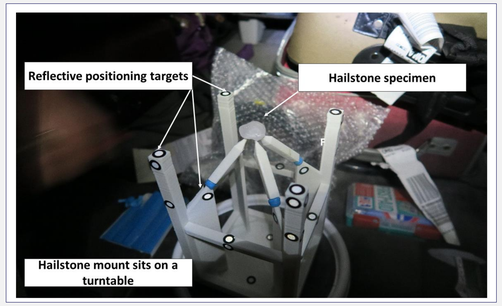

Figure 3. Photograph of the first hailstone to be 3D scanned positioned on the mount. The mount is positioned on a turntable allowing the operator to turn the stone which helps limit the need for repositioning within the vehicle.

Figure 4. Photograph of the scanner in operation during its first field deployment in September 2015. The scanner is tethered to a laptop, which allows the operator to see the captured data in real-time.

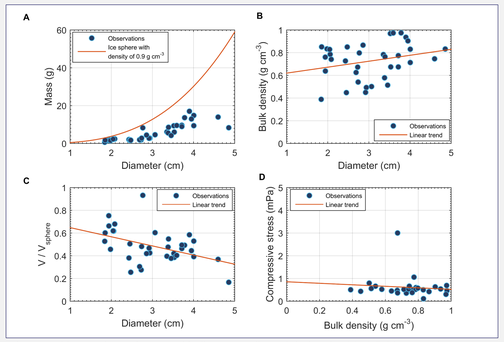

Figure 5. Observations of scanned hailstones collected during the 2016 field research program for (A) mass as a function of maximum diameter and the curve for an ice sphere with a density of 0.9 g cm^{-3} (solid orange); (B) bulk density as a function of maximum diameter; (C) ratio of the hailstone volume to the volume of a sphere of the same maximum diameter; and (D) compressive stress (proxy for strength/hardness) as a function of bulk density.

- Over 70 hailstone models collected during the Insurance Institute for Business & Home Safety's (IBHS) 2016 field measurement program
- 3D hailstone models allow for detailed examination of hailstone shapes (Fig. 5)
- Accurate measured volume and density
- Supports Heymsfield et al. (2014) that hailstones become less spherical with increasing diameter (Fig. 5C)
- Little relationship between bulk density and strength (Fig. 5D)

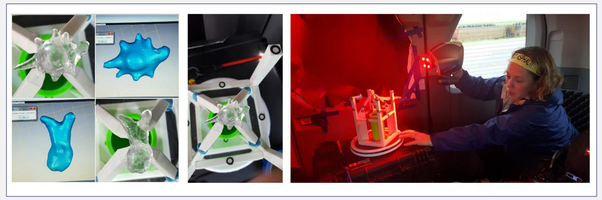

Figure 6. Photographs and screen captures (left) of selected hailstones scanned during the 2016 field program, (middle) a hailstone resting on the scanning mount, and (right) IBHS scientist Heather Estes scanning a hailstone during field operations in 2016.

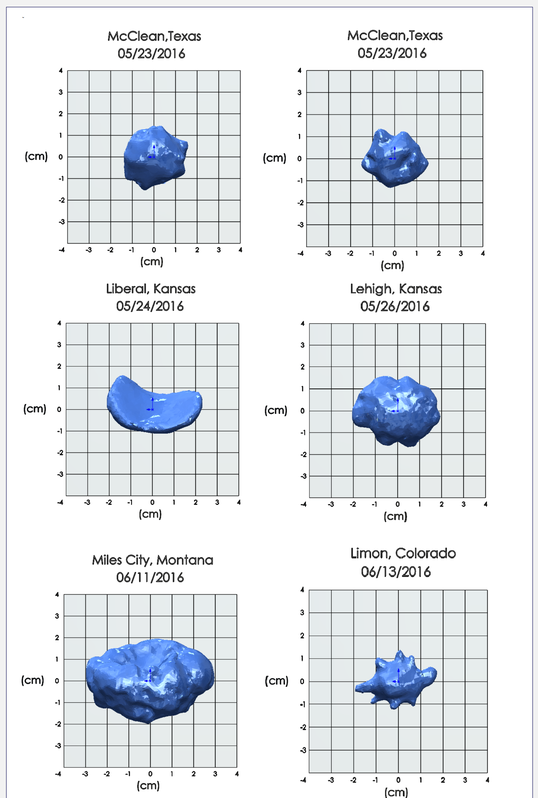

Figure 7. Subset of hailstones digital models scanned during the 2016 field program

RECORD BREAKING HAILSTONE MODELS

- Cast models of record-breaking hailstones, housed at the National Center for Atmospheric Research (NCAR), were scanned to produce digitized data of these record-breaking hailstones.
- Models were made by Dr. Charles Knight and Dr. Nancy Knight
- Digital models were used to 3D print these hailstones for display, education, and outreach

Vivian, SD July 23, 2010

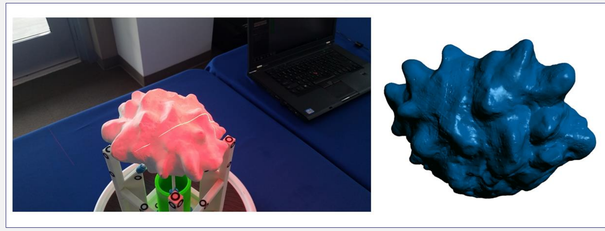

Figure 8. Photograph (left) and 3D digitized model (right) of the cast of the current United States record hailstone found near Vivian South Dakota on July 23, 2010. Note the projected laser on the surface of the cast model.

Coffeyville, KS September 3, 1970

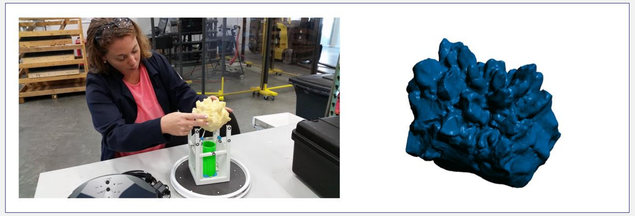

Figure 9. Photograph (left) of IBHS scientist Heather Estes preparing to scan the cast of the previous United States record-holding hailstone found near Coffeyville Kansas on September 3, 1970 and (right) the captured 3D digitized model.

Aurora, NE June 22, 2003

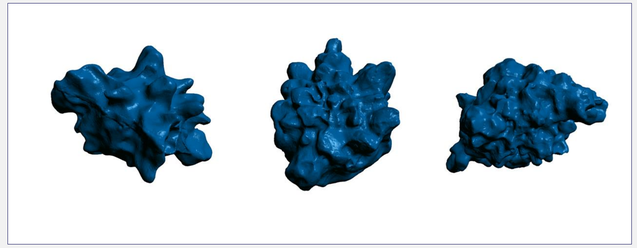

Figure 10. 3D digitized models of hailstone casts created from three large and uniquely shaped hailstones found near Aurora, Nebraska on June 22, 2003.

ACKNOWLEDGEMENTS

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