Perceptual Modeling of Icy Surfaces: A Probabilistic Approach to Visualizing Challenging Environments

**Introduction**
- In space exploration, it is important to create robust 3D maps.
- Icy moons of Jupiter and Saturn might contain water.
- Ice is difficult to model due to light absorption and internal reflection.

**Solution:** Perceptual model
- High resolution occupancy map with robust sensor model.
- Shows ice/non-ice probabilities.
- Uses data from a stereo depth sensor.
- Adapt existing occupancy mapping software to accommodate model.

**Methods**
- Episcan3D:
  - Stereo depth sensor.
  - Direction sensitive light-capturing method.
  - Different modes register only direct reflected light, "global" or indirect light, or full-intensity light.
- Octomap:
  - Open-source occupancy grid modeling software.
  - Base OcTree class used as foundation for perceptual model.

**Stereo Sensor Model**
- We want to address sensor error and remove incorrect depth values.
- Sensor model relates distance measurements to occupancy probabilities.
- Andert’s inverse stereo sensor model:
  - Error scales proportionally to measurement distance.
  - Tunable constants useful for implementation in perceptual model.

**Results**
- 8 mm resolution 3D Occupancy map, with each voxel (3D pixel) colored by the probability that ice lies at that spot (red is low probability, blue is high probability).

**Ice Probability**
- The global light image contains indirect light from internal reflection.
- Direct light visible in “current” projected pixel rows.
- Global light visible in non-current pixel rows.
- Ice probability approximated by taking a ratio of the global light to the full-intensity light in each pixel.

**Tools**

**Future Work**
- Machine learning algorithms can be applied to improve ice probability estimation algorithm.
- Outdoor trials in a non-control environment.
- Alternate modeling applications:
  - Thermal data.
  - Radiation.

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**References**