Far-field Object Characterization in the Presence of Measurement Noise

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Information on object properties including the shape of the object is of major interest. Not only does shape and attitude affect the orbit propagation via drag and solar radiation pressure and allowing for more precise object prediction, but it can also help to identify space debris objects and aid in tracing the origin. For objects that have a significant distance to the observer, only non-resolved imaging is available, which does not show details of the object. However, characterization from far field imagery, allows for early adjustments of a mission, prior to the point in time when resolved imagery is available.

One source of information on the object shape, are brightness measurements (light-curves) over time extracted from far field imagery. As only one quantity is measured, the brightness, but the potentially complex surface of a space object is sought to be determined, the problem is severely under-determined. Light curve inversion methods exist for convex objects with uniform reflection properties, following the work of Kasaaleinen et al. that has initially been developed for asteroids, assuming convex objects and (nearly) perfect measurements. However, for complex objects brightness variations might be severe, such that especially for data points in the higher magnitudes and low signal to noise ratio band. Especially when using small on board cameras, severe measurement uncertainties are unavoidable. As a result, the measurement errors large vary within a single light curve of an artificial object, from being very small at the brightest points and potentially of the order of one or more magnitudes in the fainter points.

In this paper, the effects of measurement noise on the characterization outputs is shown. In a second step, the classical light curve inversion methodology following a Gaussian Extended Image and the shape reconstruction in solving the Minkowski problem, via dual space transformation (illustrated in Fig. 1) is modified. Weights according to the measurement noise levels are introduced. With these weights, a more stable inversion can be achieved. The effect of different reflection properties and their effect on the interpretation of inversion results is shown.

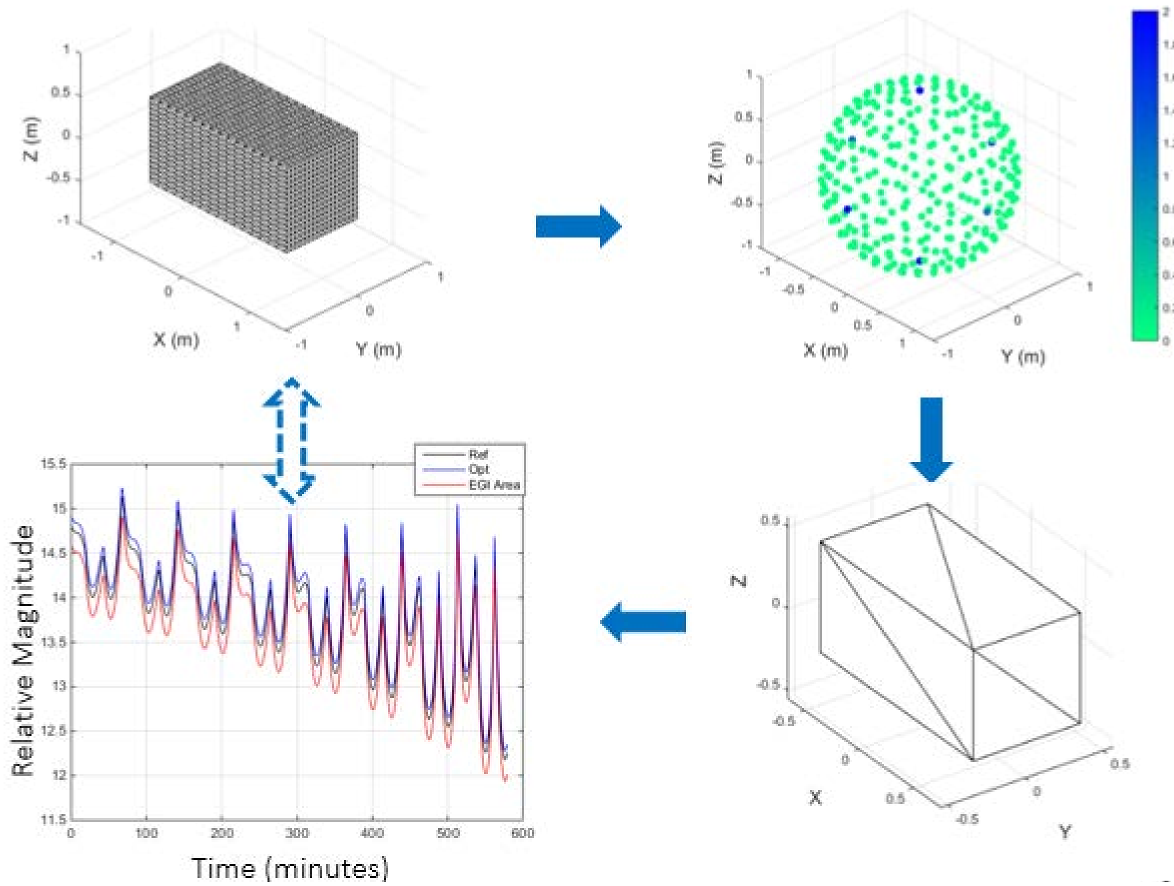

Fig 1: Classical Inversion Scheme: The cuboid on the top left is creating the blue light curve (bottom left). Using just the light curve, the extended Gaussian Image is determined, shown on the top right. With the extended Gaussian image, via dual space transformation, the cuboid is recovered. For reference the light curves from the extended Gaussian image are shown in red and from the recovered cuboid in black. As information gets lost, differences exist between the original light curve and the one stemming from the recovered cuboid.