# 2D Image Fuzzy Deconvolution and Scattering Centre Detection

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***Abstract*— A new innovative technique based on fuzzy deconvolution for scattering centre detection (F-SCD) is proposed together with its implementation in FPGA for real-time deployment in UAV and automotive collision avoidance application. F-SCD emulates the human interpretation of radar images using fuzzy measurement of features of the radar Point Spread Function (PSF) differently from other classic detection techniques. The first stage of F-SCD detects signals from noise using an image oversampling and binary integration technique. The second stage uses a fuzzy description of the radar PSF in order to discriminate among scatterers and side lobes in the radar image. The method has been implemented showing high POD, low FAR and high rejection of ambiguities even with poor time-space variant PSF.**

## I. Introduction

Modern imaging systems based on digital beam forming have the relevant feature to be easily re-configurable at run-time. The antenna/modulation scanning scheme (number of angle, range and Doppler bins, modulation period and shape) as well as the whole real-time processing pipeline can be regulated on a frame by frame fashion. The availability of massive and general purpose parallel processing (FPGA) makes it possible to implement new models of detection, discrimination and localization of targets based on fuzzy techniques normally used by humans during visual analysis and interpretation of images. Performances in detection and localization of targets/scatterers can be greatly improved by oversampling the image in respect to angle and range physical resolution limits. This is in order to measure fuzzy features such as shape and location of the point spread function lobes (main and side) which are visual clues intuitively used for localization and discrimination between effective targets (PSF main lobe) and ghosts (PSF side lobes). Using an oversampled image, a large area of the image is used to analyse each single pixel so that localization accuracy is improved and ambiguities are reduced. In Figure 1 the processing pipeline is shown – the image is analysed at different zoom scales in order to identify scatterers. The small area surrounding each pixel is processed by binary integration "M of N" in order to detect signals from noise with very low false alarm rate (FAR), and high probability of detection (POD). At the same time, a medium-sized area is also processed by the gradient operator to verify the local flatness of the image intensity. This image shape control, applied to medium-sized areas, discriminates the small-area detections using a heuristic "spot" visual clue: a scatterer in the image produces a region of pixels having more or less smooth intensity. A space variable threshold is also applied to remove signals due to system internal clutter. The location and intensity of the discriminated detections are analysed by fuzzy deconvolution using a fuzzy model of PSF on a large area surrounding the investigated pixel. Finally, the detected scatterers are classified to produce the scattering centre list available for the tracking system. The required tasks are computation intensive: real time analysis of large areas of an image requires a parallel computation paradigm that has been embedded in a FPGA IP (F-SCD IP) by Andromeda [0].

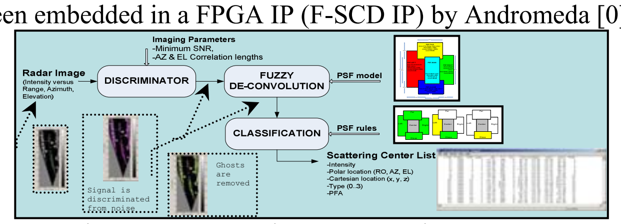


Figure 1. Fuzzy Scattering Centre Detection, F-SCD IP.

## II. Fuzzy Model of Radar Point Spread Function

The Point Spread Function, PSF, of a radar system with matched-filter receiver determines its resolution property. The PSF for a collision avoidance radar (that might be used by UAVs or automobiles) is usually a bi-dimensional function in range and azimuth having range resolution $\Delta r$ and azimuth resolution $\Delta\varphi$ , theoretically limited along the radial axis $r$ by the radio frequency bandwidth $B_{RF}$ , and along the azimuth axis $\varphi$ by the horizontal antenna aperture $L_x$ :

$$PSF(r,\varphi) = W_t\left(\frac{r}{\Delta r}\right) \cdot W_x\left(\frac{\varphi}{\Delta\varphi}\right) \quad (1)$$

where $\Delta r = c/(2 \cdot B_{RF})$ with $c$ the speed of light, $\Delta\varphi = \lambda_0 / L_x$ with $\lambda_0$ the carrier wavelength and $L_x$ the horizontal dimension of the effective antenna aperture.

The PSF is an oscillating function with a main lobe surrounded by multiple side lobes having amplitude decaying in range and azimuth. The side lobe slope is usually controlled in azimuth by antenna tapering and in range by modulation windowing. In Figure 2 a 2D image of a small trihedral corner reflector acquired with a radar operating at 77 GHz is shown. The radar image $I(r,\varphi)$ is given by the superposition of the PSF centered in the locations of the physical scatterers of the scenery and modulated by their reflectivity.

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