Single-photon, single-pixel intelligent Lidar

Gabriella Musarra[1], Alex Turpin[1,2], Ilya Starshynov[1], Ashley Lyons[1], Enrico Conca[3], Federica Villa[3], Daniele Faccio[1]

[1]*School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, United Kingdom*

[2]*Leibniz Institute of Photonic Technology, Jena 07745, Germany*

[3]*Dipartimento di Elettronica, Informazione e Biongegneria, Politecnico di Milano, 20133 Milan, Italy*

The 3D imaging of direct line of sight scenes is a crucial task with applications in self-driving vehicles, robotics and face-recognition. Recent LiDAR systems demonstrated the 3D imaging of a scene by structure illuminating the scene and collecting the return signal by using time-resolved, single-photon sensitive detectors and inferring the depth information by the time required to the light to travel back to the sensor [1-2]. However current 3D imaging systems can be bulky devices with relatively low frame rate requiring scanning parts or many pixels sensors. Here we demonstrate a 3D imaging approach for intelligent-LiDAR, iLiDAR, in which laser pulses flood (flash) illuminate the scene and the return light is focused and collected with a time-resolving, single pixel detector, in this case a single pixel Single Photon Avalanche Diode (SPAD) detector. The SPAD sensor records only the arrival times of the return photons from the whole scene in a temporal histogram via Time-Correlated Single-Photon Counting (TSCPC), whilst the 3D information is recovered through previous Artificial Neural Network (ANN) training of the system using a commercial Time-of-Flight (ToF) camera.

The experimental approach is shown in Fig.1(a): the scene, in this case a person freely moving in a room, is flood illuminated with a pulsed light source and the back-scattered light is collected by single-point, time-resolving detector and recorded in a temporal histogram. We then use a pre-trained machine learning algorithm to reconstruct the full 3D image of scene by a fully-connected layer, feed-forward ANN. In our case, the input layer corresponds to the temporal histograms, while the output layer is an image with intensity-encoded depth. We train the ANN using a ToF camera to record 8000 pairs of 3D scenes (people and targets moving in random positions within a 2x2 m^2 area up to 4 m distance) together with their corresponding SPAD histograms.

As can be seen in Fig. 1(b), the single-point LiDAR is able to distinguish the general features of the scene and its distance from the sensor. In the first column we present experimentally recorded temporal histograms. The trained artificial neural network then retrieves a 3D image of the scene (second column). The corresponding, ground-truth, 3D images acquired by the ToF camera are shown in the third column for comparison. Our results demonstrate the possibility of achieving a scanless, compact, genuine single-pixel LiDAR system, providing a new approach for real-time 3D imaging and pattern recognition.

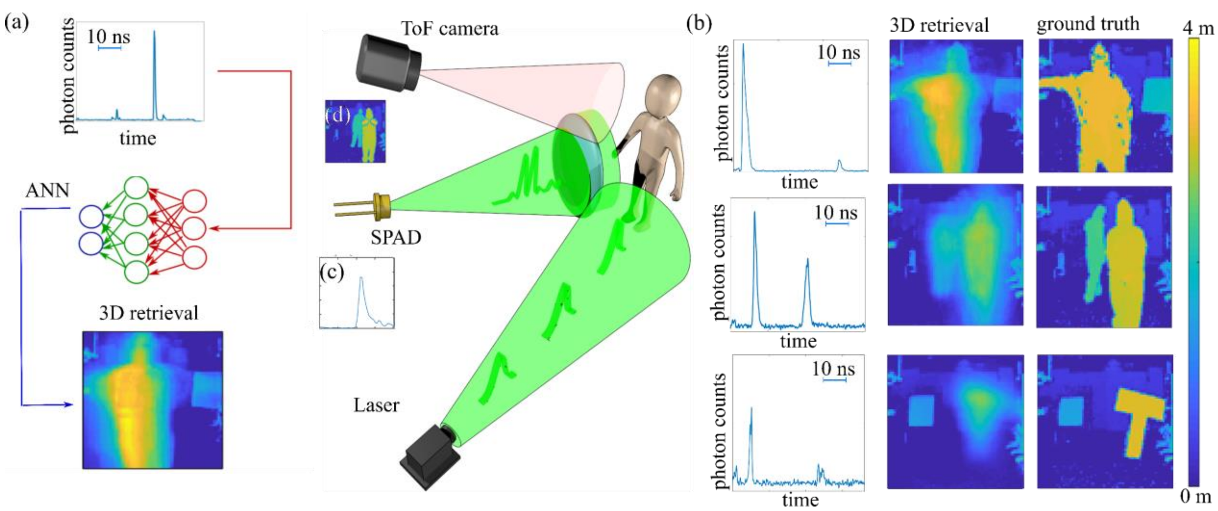

Fig.1. (a): A supercontinuum fiber pulsed laser (NKT SuperK Extreme, 20 ps pulse width, 19 MHz pulse repetition rate,) with a narrow filter at 550±50 nm is flash illuminating the scene and a single-pixel, time-resolving SPAD sensor [3] is collecting the return photons from the whole scene in a temporal histogram [inset (c)]. A ToF camera (PMD CardBoard Pico Flexx) is used to retrieve the 3D information of the scene, which is used for the training of the ANN [inset (d)]. 3D images of the scene are then obtained in a single-frame from the single-pixel temporal histograms after the ANN training. (b) Experimental results for a person, two people and a "T" target in the first, second and third row respectively. The first column represents the temporal histogram of the return photons collected by the SPAD sensor never used during the training of the ANN. The second column shows the 64x64 pixels 3D retrieved image from each histogram, while the third column shows the corresponding ground truth image.

References

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