Laser Ultrasonic Tomography using Deep Neural Networks

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Estimation of material characteristics through acoustic velocity mapping and reconstruction of the grain structure is necessary to provide detailed information about the quality of metal components. Ultrasonic tomography methods perform this characterization by measuring acoustic travel times through the test object, using numerous paths at varying angles. Consequently, this information is processed using an algorithm solving for the inverse problem. Performing these algorithms is hardware and time demanding, hence limiting real-time use of the technique.[1] This limitation compromises the use of tomography for applications where rapid evaluation is required, such as in-process inspection of manufacturing or welding.

A novel, real time tomography technique has been proposed based on Deep Neural Networks which can achieve high resolution velocity maps of anisotropic materials using computational resources of an ordinary desktop computer, using pre-trained networks.[2] In this paper, we demonstrate this technique for the first time, on experimentally acquired signals, for metallurgy. The technique is demonstrated using laser ultrasonics. In this way, the generation and detection of ultrasound were performed using lasers, leading to a completely non-contact tomography system. By applying this technique for laser ultrasonics, the tomography capabilities are expanded for use in extreme environments, on complex shapes and in places of limited access, without the requirement of any couplant.

The sample used in this study consisted of multiple, bonded metals with varying acoustic properties and velocities. Using this technique, we were able to produce velocity maps of the sample, showing the change in velocity and location of different materials within the sample.

[1] Tant, K. M. M., Galetti, E., Mulholland, A. J., Curtis, A., & Gachagan, A. (2018). A transdimensional Bayesian approach to ultrasonic travel-time tomography for non-destructive testing. *Inverse Problems*, *34*(9), 095002.

[2] Singh, J., Tant, K., Curtis, A., & Mulholland, A. (2022). Real-time super-resolution mapping of locally anisotropic grain orientations for ultrasonic non-destructive evaluation of crystalline material. *Neural Computing and Applications*, *34*(6), 4993-5010.