Optimisation and real-time control of femtosecond laser machining via deep learning

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Femtosecond lasers can enable highly precise micro-scale fabrication, due to the extremely short time scales involved. However, the interaction process between the incident laser light and the target material is highly nonlinear, and hence the machining process can be time consuming and challenging to optimise, due in part to the high sensitivity to underlying parameters such as laser pulse energy and spot size. There is therefore great interest in the development of automation techniques for both parameter optimisation and real-time control for femtosecond laser machining [1].

In recent years, deep learning has been applied to laser optimisation and laser materials processing, where it has been found to be as effective, or even more effective, than traditional modelling approaches. Here, there are two major advantages (see Figure 1). Firstly, deep learning is generally trained on experimental data, hence negating the requirement of complex modelling and theory. Secondly, neural network implementations typically take just tens of milliseconds per calculation, and hence are significantly faster than other theoretical methods.

In general, the field of deep learning can be divided into supervised learning and unsupervised learning. Supervised learning is based on the training of a neural network to complete a task related to the labelled training data. Supervised learning has been used for predicting the outcome of laser machining [2], identification of optimal parameters for machining, and identification of errors during machining [3]. Unsupervised learning is based on the concept of self-exploration by a neural network, where positive outcomes are rewarded. Unsupervised learning has been recently applied to the identification of optimal strategies for machining bespoke structures and recalibrating the strategy in real-time when errors are detected [4]. In this talk, the application of both supervised and unsupervised learning for femtosecond laser machining will be presented.

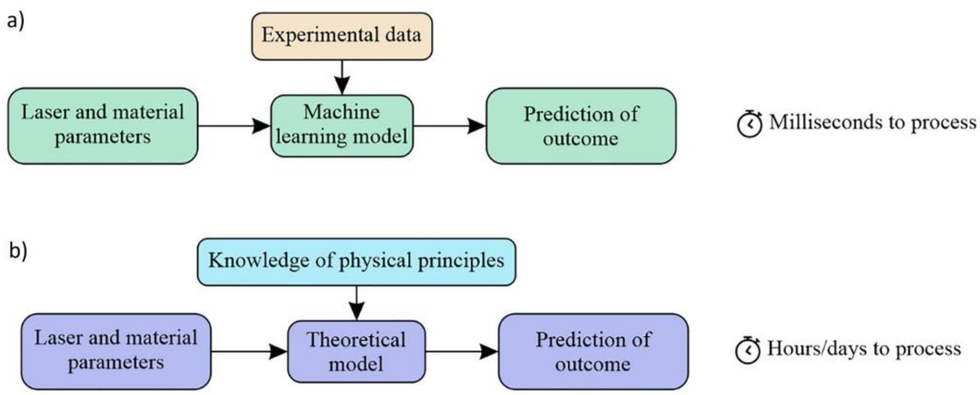

Figure 1 Concept of the application of (a) machine learning and (b) theoretical modelling for the optimisation of parameters.

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[2] Heath, Daniel J., et al. "Machine learning for 3D simulated visualization of laser machining." Optics Express 26.17 (2018): 21574-21584.

[3] Xie, Yunhui, et al. "Deep learning for the monitoring and process control of femtosecond laser machining." Journal of Physics: Photonics 1.3 (2019): 035002.

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