Deep learning enables cross-state image restoration through a flexible multimode fibre

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Introduction

Multimode fibres (MMF) have recently attracted significant renewed interest in applications such as optical communication, imaging and optical trapping [1]. This is mainly due to the extremely high information-transmission capacity offered by the thousands of fibre modes transmitting in the MMF. However, MMF transmission is highly sensitive to external perturbations and environmental changes, resulting in MMF transmission channels being highly variable and random. This largely limits the practical application of MMFs and hinders the full exploitation of their information capacity.

Objective

Here, we present a deep-learning-based framework [2] to achieve cross-state image restoration through a flexible MMF in order to turn MMFs into practical imaging components or communication devices. We utilise the outstanding representation power of a deep neural network (DNN) to transmit images through a single MMF in three scenarios: image transmission simulation using measured transmission matrix (TM), image retrieval through a stationary MMF with different transmission states, and image retrieval through a flexible MMF subject to continuous shape variations (CSV).

Methods

A. DNN Implementation

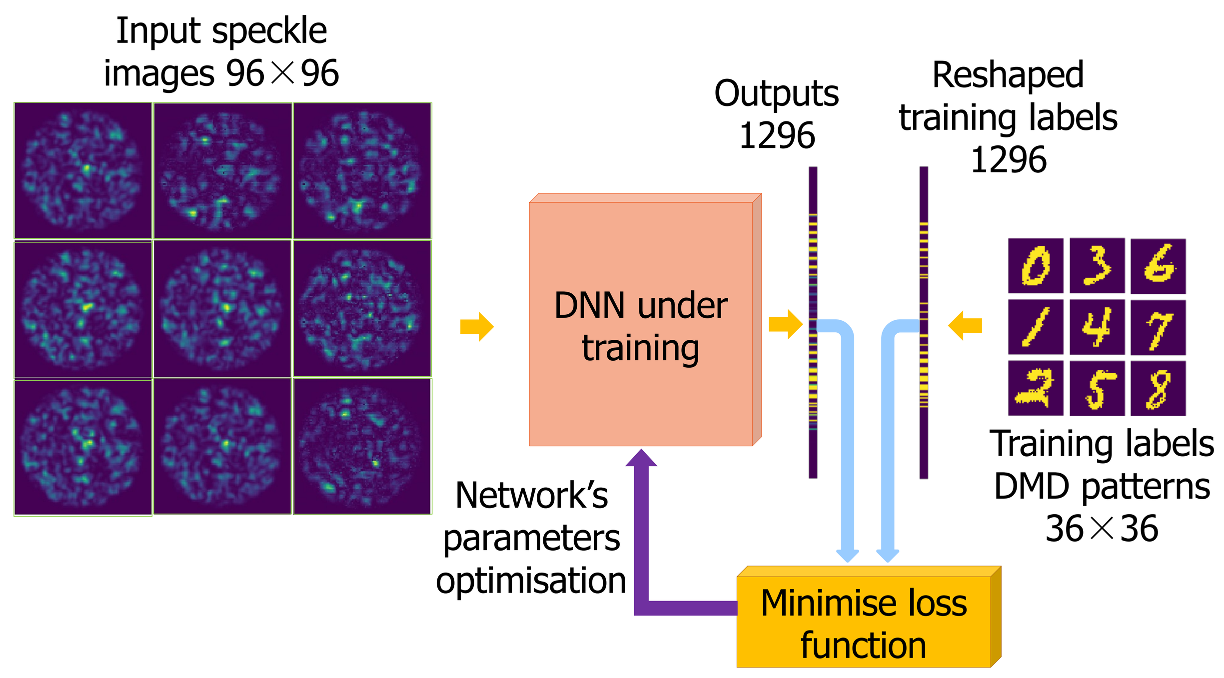

Fig. 1. Schematics of the deep neural network trained for imaging through an MMF.

B. Simulation with measured TM

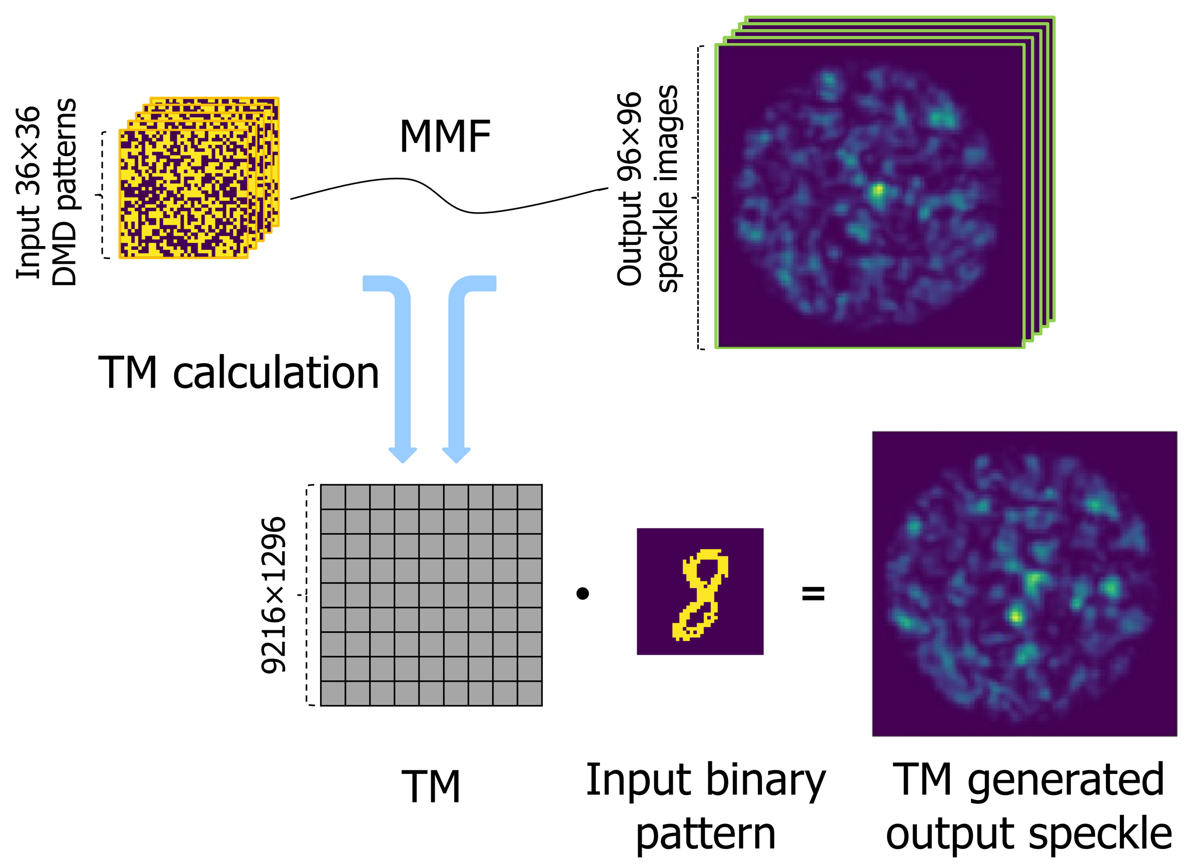

Fig. 2. Schematic of speckle generation using TM.

C. Cross-state image retrieval through a stationary MMF

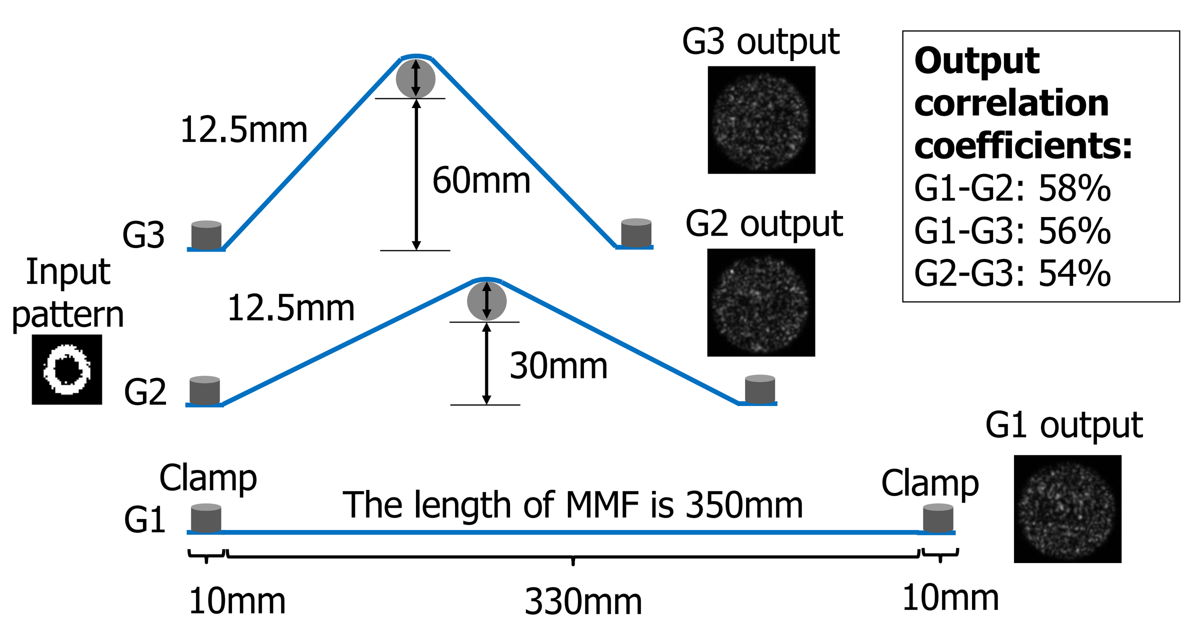

Fig. 3. MMF configurations: G1, G2 and G3 are three geometric states for the MMF under testing.

D. Deep learning a flexible MMF subject to CSV

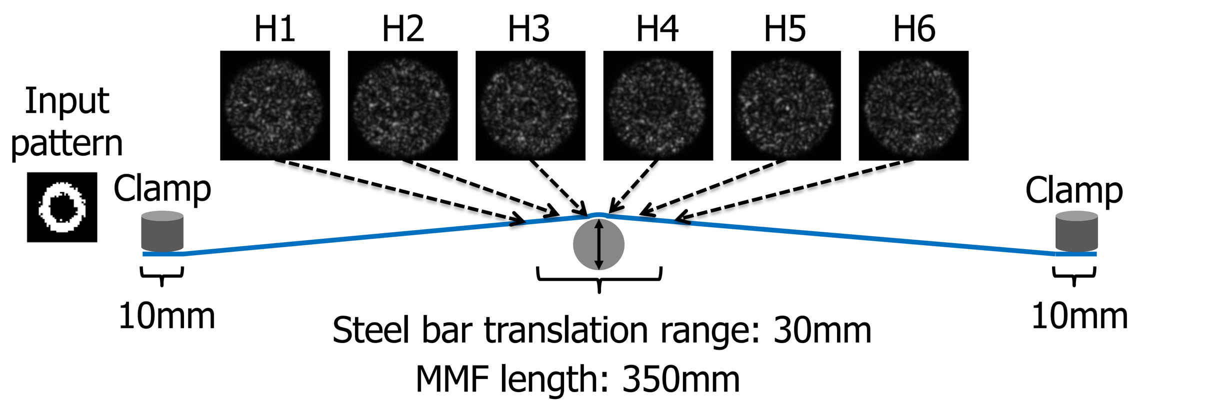

Fig. 4. Experimental configuration to apply CSV to the MMF under testing.

Results

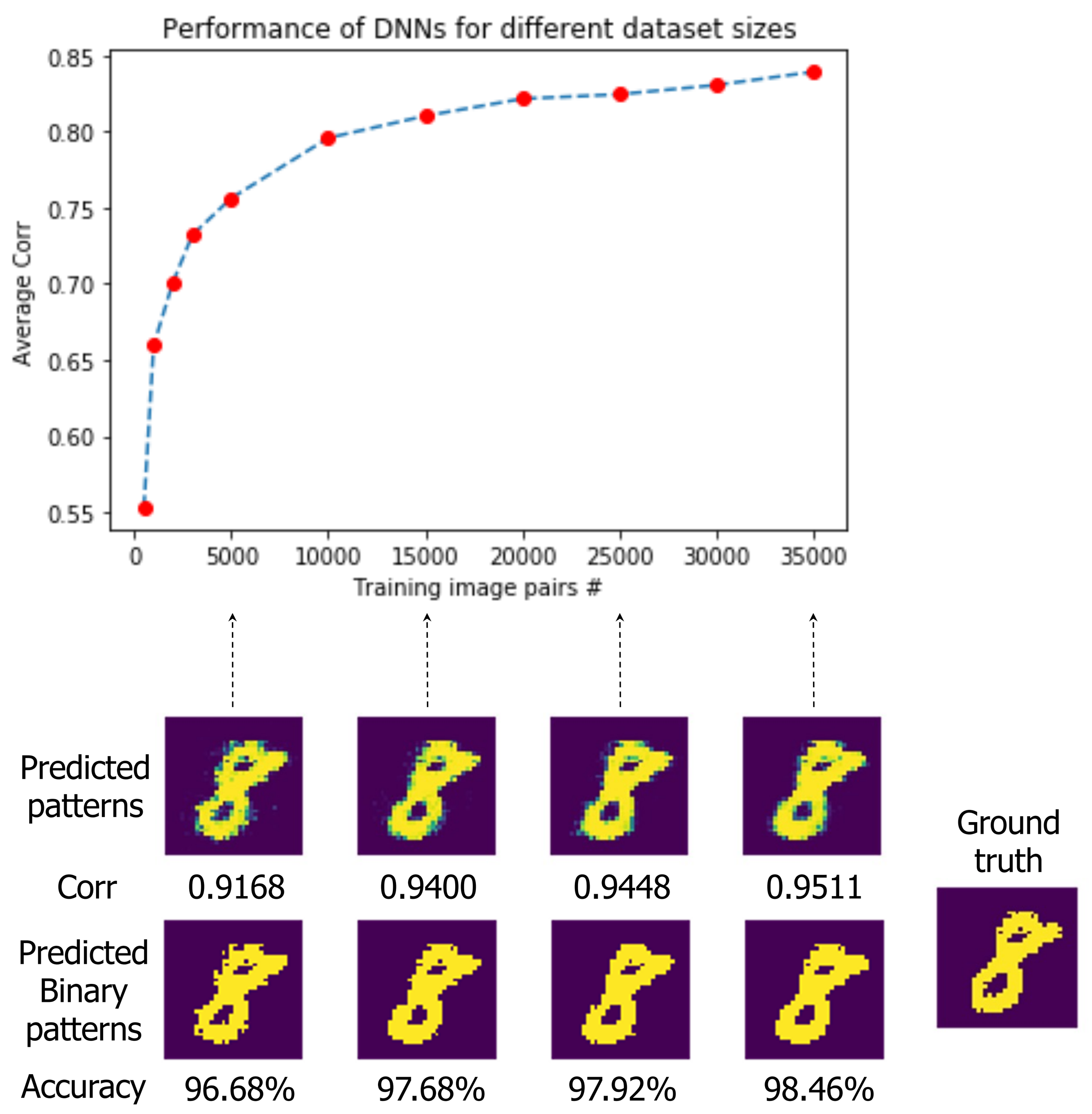

Fig. 5 The network performance at different sizes of randomly chosen training datasets.

Conclusions

In conclusion, we demonstrate experimentally that distorted images through a flexible MMF subject to CSV can be recovered successfully by an appropriately trained deep neural network without knowing the exact MMF geometrical states.

References

1. Plöschner, et al. "Seeing through chaos in multimode fibres," Nature Photonics 9, 529 (2015).
2. Fan, et al. "Deep learning enabled scalable calibration of a dynamically deformed multimode fiber," Advanced Photonics Research, 2100304 (2022).