

# A Neural Network Based Adaptive MIMO-VLC System

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**Abstract**—This paper presents an indoor MIMO-VLC system that adaptively coordinates the number of MIMO channels according to the channel conditions. We employ a neural network to select the optimal pattern of channels, depending on the channel matrix.

**Keywords**—Visible Light Communication (VLC), Multiple-Input Multiple-Output (MIMO), Transmitter Coordination, Neural Network

## I. INTRODUCTION

In indoor visible light communications (VLC), Multiple-Input Multiple-Output (MIMO) VLC enables the use of multiple transmitters and multiple receivers at the same time. The possibility of parallel data transmission and spatial multiplexing leads to the potential of higher spectral efficiency and higher data rates [1]. In [2], we proposed the Channel Condition-based Transmitter Coordination (CCTC) algorithm to improve the overall data rate of the MIMO system. The CCTC algorithm can find the optimal transmitter pattern by assigning transmitters to several groups and transmitting the same data in each group, which can be regarded as the adaptive combination of ganging and spatial multiplexing schemes. It can also maximise the data rates of each channel group. However, the CCTC algorithm has great computational complexity, and requires a large amount of computing time.

Artificial neural networks (ANN) are a set of computing systems that roughly simulate how the human brain analyses information [3]. They can learn knowledge through detecting relationships in data [3]. In this article, a feedforward multi-layer perceptron (MLP) ANN is employed to replace the CCTC algorithm and predict the optimal transmitter pattern. The ANN-based MIMO-VLC achieves the overall data rate as good as the CCTC algorithm at significantly lower computing complexity.

## II. SYSTEM MODEL

Fig. 1 presents the configuration of a typical indoor MIMO-VLC system [4].  $N_t$  LEDs are installed on the room ceiling, transmitting information to the receiver on the receiver plane. The receiver is an angular diversity receiver with  $N_r$  receiver elements. Each receiver element detects different light intensities from different LEDs. The detailed settings of the system are given in [2].

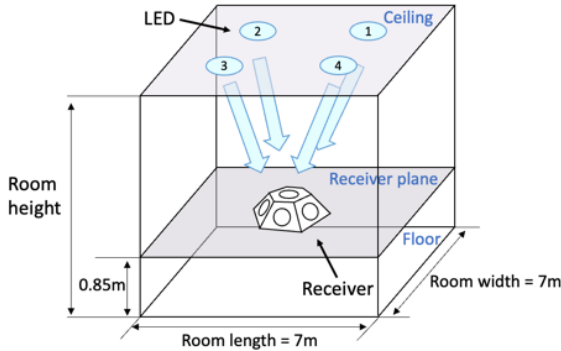


Fig. 1. Architecture of a typical indoor MIMO-VLC system.

TABLE I. PARAMETER [2]

Parameters	Values
Room size (width $\times$ length $\times$ height)	7 m $\times$ 7 m $\times$ 3/4.5/4 m
Receiver plane height	0.85 m
Numbers of LEDs ( $N_t$ )	4
Numbers of REs ( $N_r$ )	7
Modulation power per LED ( $P_{LED}$ )	1 W
LED pitch	2.5 m
Lambertian order ( $m$ ) (transmitter semi-angle ( $\theta_{1/2}$ ))	1 ( $60^\circ$ )
Collection area of each RE ( $A_j$ )	100 mm <sup>2</sup>
Half-angle field of view of receiver ( $\beta_c$ )	$33^\circ$
Concentrator refractive index ( $n_c$ )	1.5
LED and Receiver bandwidth	8.4 MHz
Detector responsivity ( $\rho$ )	0.4 A/W [4]
Pre-amplifier noise current density ( $i_{amp}$ )	5 pA/Hz <sup>1/2</sup> [4]
Ambient light photocurrent density ( $\gamma_{ambient}$ )	10.93 A/(m <sup>2</sup> ·Sr) [5]

The MLP ANN is used to estimate the optimal transmitter pattern at each user location. Fig. 2 shows the architecture of the network. The system is a two-layer feed-forward network, including one input layer, which uses the channel matrix as inputs, one hidden layer and one output layer, which outputs the optimal pattern index. After obtaining this, the data rate of each channel group is maximised by the CCTC algorithm.

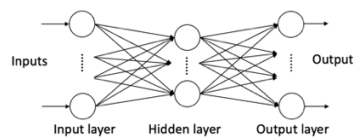


Fig. 2. Architecture of the MPL ANN.

To find the optimal transmitter pattern, the MIMO channel matrix between the transmitters and the receivers is estimated using established link modelling techniques [2]. There are  $N_r \times N_t$  weights in the channel matrix, and the number of neurons at the input layer is set to this number. The input layer is connected with the hidden layer, and the input layer uses the sigmoid function as the activation function. The selection of the transmitter pattern is a pattern recognition problem, and the neural network classifies the inputs into a set of target categories, each corresponding to a particular pattern of transmitters (representing a combination of ganging and spatial multiplexing). The output layer has a softmax function and the number of neurons at the output therefore equals the number of different transmitter patterns. The training algorithm used is Bayesian regularisation, and the output performance is evaluated by calculating the cross-entropy between the real value and the value predicted by the MLP ANN. Once the pattern is known the performance of each of the data streams is optimised using Decision Feedback Equalised On-Off-Keying as a modulation scheme. Details of the channel modelling are given in [2]. The system parameters are shown in Table I.

### III. SIMULATION AND RESULTS

In this section, the overall data rate obtained from the CCTC algorithm and the MLP ANN are compared.

#### A. System Settings

At the input side, the number of the neurons is  $N_r \times N_t = 28$ . The hidden layer has 10 neurons. The number of neurons at the output side is 15 as there are 15 types of transmitter pattern [2]. The MLP ANN system has two phases: a training phase and a testing phase. In the training phase, the rooms with size  $7\text{m} \times 7\text{m} \times 3\text{m}$  and  $7\text{m} \times 7\text{m} \times 4.5\text{m}$  are employed. 225 channel matrices obtained from 225 ( $15 \times 15$ ) different user locations (picked from the receiver plane with  $0.5\text{m}$  array pitch) are employed for each room. In total, there are 450 channel matrices used as the input. The corresponding 450 patterns calculated from the CCTC algorithm are used as the target. In the testing phase, the room size is selected as  $7\text{m} \times 7\text{m} \times 4\text{m}$  with  $8 \times 8 = 64$  testing points and  $1\text{m}$  array pitch.

#### B. Performance Comparison

Fig. 3 shows the top view of the overall data rate distribution for the indoor MIMO-VLC system. Fig. 4 presents the overall data rates versus distance from the receiver to the room centre. Both figures show that the overall data rates derived from the CCTC algorithm and the MLP ANN are in good agreement. This is achieved, even though the height of the room used for testing is different from that used for training room. These promising results indicated that the MLP ANN can select an optimal pattern for a wider range of test data than that used for training.

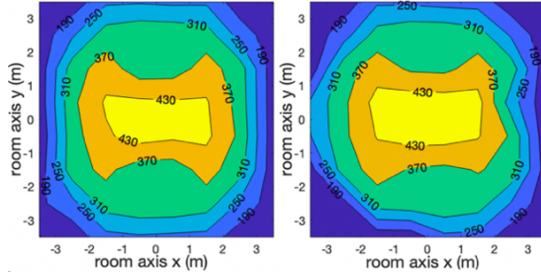


Fig. 3. Overall data rate (Mbps) distribution for the MIMO-VLC system with CCTC algorithm (left) and MLP ANN (right).

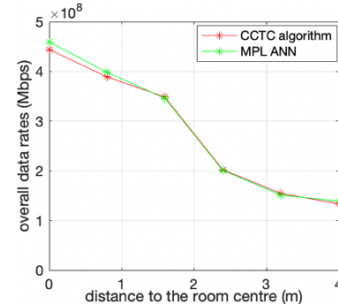


Fig. 4. Overall data rates versus distance to the room centre.

Overall, the computing time for the CCTC algorithm is  $2.9575 \times 10^4$  s, and for the MLP ANN is  $6.7617 \times 10^3$  s. The MLP ANN is more than a factor of four times faster than the CCTC algorithm, showing that it substantially reduces the computational complexity with almost no reduction in overall data rate.

### IV. CONCLUSION

In the article, a neural network is used to select an optimal MIMO transmitter pattern, given certain constraints. The neural network performs almost as well as an exhaustive search technique (CCTC algorithm), with much lower computational complexity. Ideally, the system would be trained using a small data set and give good results for a wide range of different room, transmitter and receiver configurations, and work is underway to understand how adaptable and robust the technique is.

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