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# Machine Learning –Based Massive Augmented Spatial Modulation for IOT VLC Systems Using Arduino

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**ABSTRACT:** Massive Multiple-Input Multiple-Output (MIMO) technology aims to further the diversity/multiplexing gains of wireless communication systems. Spatial modulation (SM) is a renowned low-complexity MIMO scheme that jointly uses transmitting source indices along with the data stream to convey information. However, the reliability of the spatial stream in SM is significantly influenced by the correlation between channel coefficients. Hence, applying massive-MIMO in visible light communications (VLC) remains an under-investigated area of research, due to the ill-conditioned massive-MIMO VLC channel. Augmented SM (ASM) is an approach that overcomes the channel uniqueness requirement for SM-based VLC systems. This letter adopts massive-ASM for Internet-of-Things applications with a focus on investigating ASM's complexity and introducing different machine learning based receiver designs, including; support vector machine (SVM), logistic regression (LR), and a neural network (NN). The computational time and transmitter identification accuracy are compared and the system's bit-errorrate performance is evaluated.

**KEYWORDS-**MIMO, spatial stream, light communication ,channel requirement, support vector machine.

## I. INTRODUCTION

Visible light communications (VLC) has been highly acknowledged as a promising technology to complement traditional radio frequency (RF) communications due to the broadly available and unregulated light spectrum. Multipleinput multiple-output (MIMO) techniques have been employed in VLC to mitigate the bandwidth limitations imposed by current off-the-shelf light-emitting diodes (LEDs) through providing multiplexing/diversity gains while reserving the complexity and compactness in size constraints for applications such as Internet-of-Things (IoT). Spatial Modulation (SM) is a digital modulation concept for MIMO systems that enhances the data rate beyond that of single-element systems while maintaining low complexity transceiver design in comparison to spatial multiplexing schemes. The multiplexing gain in SM is realized through the conventional data stream and spatial stream, which identifies single active transmitting element. Hence, the data rate can be increased by a factor up to the logarithm of the number of transmitting elements, making it a perfect candidate for massive-MIMO applications. However, spatial uniqueness plays a critical role in determining the multiplexing gain of SM, and the spatial channels in VLC are usually highly correlated. Thus, the applicability of massiveMIMO in VLC systems remains challenging [1]. Multiple-input single-output (MISO) realizations have gained interest in IoT deployment scenarios, as the IoT devices can be equipped with a single receiving element, while the access point (i.e. transmitter) can have multiple elements. One of the very few works that implemented MISO optical SM is [2]. The work presents an adaptive power allocation algorithm for a 2x1 configuration in pulse amplitude modulation (PAM) optical MISO SM. However, the analysis did not include the case when the channel matrix is singular.

## II. OBJECTIVE

Machine learning uses algorithms to parse data, learn from that data, and make informed decisions based on what it has learned. Deep learning structures algorithms in layers to create an “artificial neural network” that can learn and make intelligent decisions on its own. The purpose of machine learning is to discover patterns in your data and then make predictions based on often complex findings to answer business questions, detect and analyze trends and help solve problems. The goal of the internship is to improve current algorithms and propose innovative solutions for filtering and fusing the various signals. Deep learning could also be considered as an improvement of existing techniques.

## III. LITERATURE SURVEY

Applying massive-MISO in RF is facilitated by the rich scattering nature of the RF channel. SM takes advantage of the presence of the large transmitting elements array at the transmitter, while omitting co-channel interference by activating only one antenna at a time. Unlike RF, the transmit-to-receive links in VLC systems vary in independence and the channel impulse responses do not always represent a unique point/signature [4]. Hence, performance of massive-SM in VLC deteriorates significantly when the transmit-to-receive links become highly spatially correlated. A. Detection in single-carrier SM-Based VLC Systems Maximum-Likelihood detection (MLD), which is based on the maximum likelihood principle, remains the most popular detection approach due to its optimality. MLD of SM systems involves the joint detection of both the transmitting element index and the transmitted symbol. Under the assumption of perfect CSI knowledge at the receiver,

## IV. METHODOLOGY

In ASM, the data transmitted from each transmitter is preconditioned using a reserved codeword. Thus, transmitter index identification becomes independent of channel conditions. Then, the ASM receiver recovers the data by solving an Nt hypothesis problem. The transmit scheme of ASM is simple; however, similar to conventional SM, the complexity of optimal detection linearly grows with Nt. vspace-10pt A. ASM vs. Conventional SM As previously mentioned, although SM is a promising communication technique, its performance deteriorates in highly spatially correlated channels. For illustration, considering a modified version of the famous indoor VLC scenario of a  $5 \times 5 \times 3$  m<sup>3</sup> room model presented in [5] and using Eq. (2), the probability of correctly detecting the spatial information for conventional SM systems is illustrated in Fig. 1. The ceiling of the room is modeled to have 1000 transmitters (emulating a massive scenario) that are centered in the room with a vertical and horizontal separation distances of 0.125 m, while the receiver is placed 0.85 m from the floor. As can be observed, the reliability of the spatial stream varies as the receiver sweeps within the room. Additionally, the probability of correct detection drops to zero when the receiver is located in the center, as the channel coefficients from all transmitters are identical and hence spatial identification becomes unachievable. On the other hand, ASM relaxes the uniqueness constraint of conventional SM and replaces it with deterministic signal alterations performed and reversed at the transmitting and receiving ends, respectively. The performance of ASM does not rely on channel uniqueness, thus, only the performance for SM is shown as ASM's performance is constant throughout the room.

## V. APPLICATIONS

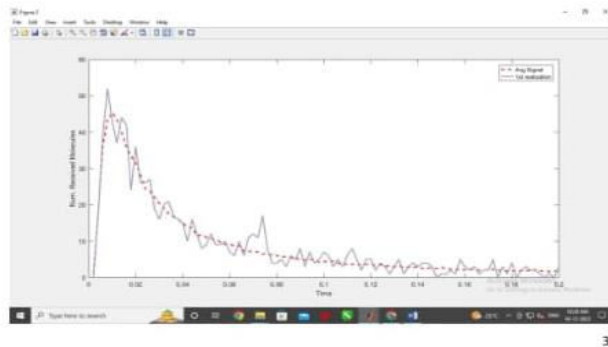
Automated machine learning enables organizations to use the baked-in knowledge of data scientists without expending time and money to develop the capabilities themselves, simultaneously improving return on investment in data science initiatives and reducing the amount of time it takes to capture value.

## VI. FUTURE SCOPE

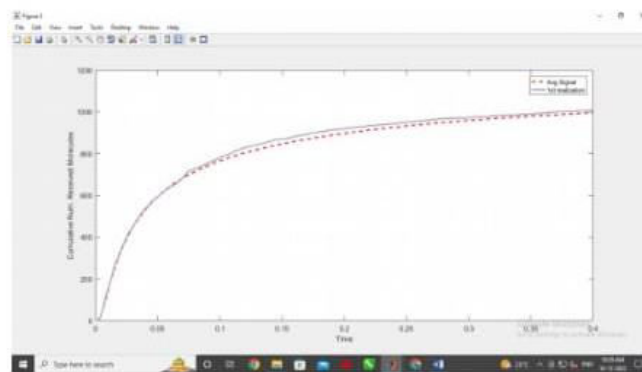
The scope of machine learning in India, as well as in other parts of the world, is high in comparison to other career fields when it comes to job opportunities. According to Gartner, there will be 2.3 million jobs in the fields of artificial intelligence and machine learning by 2022. Machine learning uses statistical patterns to make accurate predictions, the technology is also helpful in document analysis and high-frequency trading, etc.,

### VII. RESULT

Results showed that with the single-layer NN, computation time remained almost constant irrespective to the number of transmitting elements, which showed a tremendous potential for ASM’s massive-MIMO deployment while satisfying the low-complexity criterion of IoT applications.



The work presents an adaptive power allocation algorithm for a 2×1 configuration in pulse amplitude modulation (PAM) optical MISO SM. However, the analysis did not include the case when the channel matrix is singular.



### VIII. CONCLUSION

ASM’s complexity was investigated to allow its adoption in massive-MIMO IoT VLC settings. Various ML techniques were proposed to decrease the computational complexity of ASM. Simulation results showed that SVM, LR, and singlelayer NN can be used to identify 1000 transmitters with an accuracy above 99% and without the need of channel knowledge or channel coefficients uniqueness using different hardware architectures. Results showed that with the single-layer NN, computation time remained almost constant irrespective to the number of transmitting elements, which showed a tremendous potential for ASM’s massive-MIMO deployment while satisfying the low-complexity criterion of IoT applications.

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