# Fiche de Lecture

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| 1er auteur & année | Antonia Ivanda; 2025 |
| Titre | Exploring Applications of Convolutional Neural Networks in Analyzing Multispectral Satellite Imagery: A Systematic Review |
| Type de document | Article scientific |
| Auteurs | Antonia Ivanda\*, Ljiljana Šerić, and Maja Braović |
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| Mots clés | remote sensing; MultiSpectral Images (MSI); satellite images; Convolutional Neural Networks (CNN);  machine learning; classification; regression; segmentation  For more KeyWords look to the file the green words. |
| Source (référence normalisée) | <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10856922> |
| Degré de liaison avec l’axe de recherche | **Moyen (3/5)**  L'article traite des applications des CNN pour l'analyse d'images satellitaires multispectrales, ce qui est proche à mon sujet sur le traitement des données manquantes via le ML/DL.  Les méthodes discutées (1D/2D/3D/4D-CNN) pourraient être adaptées pour imputer ou reconstruire des données manquantes. |
| Informations extraites du document  (Résumé si existant, définitions, figures, etc.) | **Abstract:**  Remote sensing is of great importance for analyzing and studying various phenomena occurrence and development on Earth. Today is possible to extract features specific to various fields of application with the application of modern machine learning techniques, such as Convolutional Neural Networks (CNN) on MultiSpectral Images (MSI). This systematic review examines the application of 1D-, 2D-, 3D-, and 4D-CNNs to MSI, following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.  This review addresses three Research Questions (RQ): **RQ1: “In which application domains different CNN models have been successfully applied for processing MSI data?”, RQ2: “What are the commonly utilized MSI datasets for training CNN models in the context of processing multispectral satellite imagery?”, and RQ3: “How does the degree of CNN complexity impact the performance of classification, regression or segmentation tasks for multispectral satellite imagery?”.** Publications are selected from three databases, Web of Science, IEEE Xplore, and Scopus. Based on the obtained results, the main conclusions are: (1) The majority of studies are applied in the field of agriculture and are using Sentinel-2 satellite data; (2) Publications implementing 1D-, 2D-, and 3D-CNNs mostly utilize classification. For 4D-CNN, there are limited number of studies, and all of them use  segmentation; (3) This study shows that 2D-CNNs prevail in all application domains, but 3D-CNNs prove to be better for spatio-temporal pattern recognition, more specifically in agricultural and environmental monitoring applications. 1D-CNNs are less common compared to 2D-CNNs and 3D-CNNs, but they show good performance in spectral analysis tasks. 4D-CNNs are more complex and still underutilized, but they have potential for complex data analysis. More details about metrics according to each CNN are provided in the text and supplementary files, offering a comprehensive overview of the evaluation metrics for each type of machine learning technique applied.  For more definitions look to the file the yellow notes.  For the figures look for the ones in yellow. |
| Commentaires personnels  (Résumé personnel, jugement, usage possible, association d’idées, etc.) | L’article propose une revue importante et utile pour mon sujet de recherche, surtout en ce qui concerne les technologies utilises dans ce domaine des images satellitaires. Sachant qu’il offre une vue d'ensemble précieuse des CNN pour l'imagerie satellitaire, mais n'aborde pas explicitement le traitement des données manquantes. Il met en évidence des lacunes et les limites des ND-CNNs avec N dans l’intervalle [1,4] pouvant être exploitées. L’analyse des performances par architecture CNN est riche et bien structurée. Approprié pour positionner mes travaux dans l’état de l’art. De plus, il donne un traitement très clair en ce qui concerne les domaines d’utilités de CNNs.  L’article a mentionne aussi les types de coefficients (ou key metric in ML/DL analysis) that tell us how well our modelis good in the different ley metrics in every types of ML techniques, such as: regression, classification and Image segmentation.  L’article a mentionné aussi les types de dataset, satellite images, the domaines of use them and those details. |
| Emplacement physique du document primaire | **Online :** <https://drive.google.com/file/d/1Y1YC4TTVKhA5msiJXY1K_WHzSKoCo3pq/view?usp=drive_link> |
| Autres références bibliographiques | Voir les références en bleu dans l’articles comme primaire et les autres comme secondaire. |
| Idée générale de l’article | Cet article offre une étude comparative entre les ND-CNNs avec N dans l’intervalle [1-4] en les appliquant avec les MSI. Il vise à analyser comment différentes architectures de ND-CNNs (1D, 2D, 3D et 4D) sont utilisées dans des domaines variés (ex. : agriculture, végétation, eau, urbain) en fonction des données open (ex. : sentinel, Landsat). |
| L’objective | L’objective est de classer et évaluer les applications CNNs pour les MSI selon leurs performances, les ML techniques utilisées, les métriques utilisées.  À identifier :   * Dans quel domaine d’application chaque CNNs est utile * La performance des models ML traditionnels pour chaque CNNs   “**The objective of this systematic review is to assess the literature on the possibilities, challenges and gaps in the use of deep learning models, specifically 1D-, 2D-, 3D-, and 4D-CNNs, on multispectral imaging data. In particular, this research investigates the trends in the application domain of CNNs, the type of satellite data, and the machine learning technique used.**” |
| Problematique | **Évaluer l'efficacité des différentes architectures CNN (1D à 4D) dans le traitement des images satellites multispectrales (MSI), selon le domaine d’application et les jeux de données utilisés.** |
| L’approche propose | Analyser et comparer l’utilisation des CNN 1D, 2D, 3D et 4D dans les publications scientifiques récentes à travers plusieurs bases de données |
| Les technologies utilise | * CNN (Convolutional Neural Networks) en 1D, 2D, 3D et 4D * Techniques de machine learning et deep learning * Datasets satellites MSI : **Sentinel-2, Landsat 8/9, MODIS, MERIS, SeaWiFs, VENuS, WorldView, Gaofen, Proba-V, EnMAP, AVIRIS, PRISMA** * Tâches étudiées : classification, régression, segmentation * Évaluation via des métriques telles que : **Accuracy, F1-score, précision, rappel, R², RMSE, MAE, Producer’s accuracy, User’s accuracy, Kappa coefficient, Dice coefficient, IoU, MIoU**. |
| Résultats attendus et obtenus | This article aims to answer the three Research Questions (RQs):   * **RQ1:** In which application domains different CNN models have been successfully applied for processing MSI data? * Les CNNs sont appliqués surtout en agriculture, classification de végétation, suivi de l’eau, reconnaissance urbaine et environnement. * **RQ2:** What are the commonly utilized MSI datasets for training CNN models in the context of processing multispectral satellite imagery? * Les jeux de données les plus utilisés sont **Sentinel-2 (le plus utilise),** **Landsat8/9**, **MODIS**, **WorldView**, **Gaofen**, **Proba-V**, etc. * **RQ3:** How does the degree of CNN impact the performance of classification, regression or related to application domains, datasets, and model performance segmentation tasks for multispectral satellite imagery? * **1D-CNN** : Performantes pour l'analyse spectrale pure (ex. classification de végétation), mais ignorent les motifs spatiaux. * **2D-CNN** : Dominantes pour les tâches spatiales (ex. urban), ils sont les plus utilisés (faciles, performants) * **3D-CNN** : Supérieures pour les analyses spatio-temporelles (ex. agriculture, environnement). * **4D-CNN** : Sous-utilisées (3 études seulement), mais prometteuses pour les dynamiques complexes. |
| Information can be use in other places | **Key metrics for machine learning techniques**   * **For classification:**   Classification involves examining the connections among a group of “objects” to determine whether the data can be accurately summarized by a limited number of categories representing similar objects. There are different types of classification, of which the most popular are supervised and unsupervised.  F1: Accuracy is a measure that refers to the total data accurately predicted by the trained classifier when tested on unseen data. It ranges from 0 to 1, or in percentage terms from 0% to 100%, where accuracy  closest to 1 or 100% suggests that the classifier is more accurate.  F2: The F1-score is the harmonic mean of the precision and recall metrics. Precision is the ratio of correctly predicted positive observations to the total number of predicted positive observation. Recall is the ratio of correctly predicted positive observations to all observations in the actual class. The best value achieved by the F1-score is 1 (perfect precision and recall) and the worst value is 0.   * **For regression:**   Regression is a statistical method used to investigate the relationship between species and the environment, based on observations of species and environmental variables at a series of locations.  F1: R2, also known as the coefficient of determination, determines the proportion of variance in the dependent variable that can be explained by the independent variables. It provides information on how well the observed values match the predicted values and can be expressed as a value or percentage, ranging from 0 to 1 or 0% to 100%.  F2: RMSE is the square root of the mean of the squares of all the errors. It indicates how close the line of best fit is to the set of points  F3: MAE provides the average value of the absolute difference between the observed values and the predicted values   * **For Image segmentation:**   Image segmentation is a technique defined as the process of dividing or partitioning an image into homogeneous parts, called segments. This is particularly useful for applications such as image compression or object detection, as processing the entire image for these types of applications is inefficient. Therefore, image segmentation is used to segment parts of the image for further processing.  F1: Accuracy, F1-score, precision, and recall have same definition as for  classification. Producer’s and user’s accuracies are commonly used in segmentation tasks.  F2: Producer’s accuracy indicates how well a training set pixel is classified for a given coverage type. User’s accuracy indicates the probability that a pixel classified as belonging to a certain class actually represents that class on the ground.  F3: The Kappa coefficient indicates how much the classification is better compared to a classification where each pixel is randomly assigned a  class value.  F4: The Dice coefficient is a metric used to compare the similarity of two samples. The Dice coefficient is twice the overlapping area of the two segmentations divided by the total number of pixels in the two images.  F5: IoU measures the overlapping area between the predicted segmentation and the true segmentation, representing the overlapping area divided by the union area of the predicted segmentation and the true segmentation.  F6: MIoU is the average of the IoU values calculated for each class.  **Les types des images satellitaires**  Satellite images are: Multispectral, hyperspectral, UAV imagery, Unmanned Aerial Vehicle (UAV), and Synthetic Aperture Radar  (SAR).  **Les dataset satellitaire**  Sentinel, landsat, MODIS, MERIS, SeaWiFs, VENuS, WorldView, Gaofen, Proba-V, EnMAP, AVIRIS, PRISMA |
| Perspectives | 1. Des études comparatives entre 1D-, 2D-, 3D- et 4D-CNNs sur **les mêmes tâches et les mêmes jeux de données**. 2. L’utilisation des CNNs dans les domaines de regression et segmentation 3. Seules 3 études utilisent des 4D-CNN |