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arXiv:2103.05969v1 [eess.IV] 10 Mar 2021

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# Self-supervised Change Detection in Multi-view Remote Sensing Images

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***Abstract*—The vast amount of unlabeled multi-temporal and multi-sensor remote sensing data acquired by the many Earth Observation satellites present a challenge for change detection. Recently, many generative model-based methods have been proposed for remote sensing image change detection on such unlabeled data. However, the high diversities in the learned features weaken the discrimination of the relevant change indicators in unsupervised change detection tasks. Moreover, these methods lack research on massive archived images. In this work, a self-supervised change detection approach based on an unlabeled multi-view setting is proposed to overcome this limitation. This is achieved by the use of a multi-view contrastive loss and an implicit contrastive strategy in the feature alignment between multi-view images. In this approach, a pseudo-Siamese network is trained to regress the output between its two branches pre-trained in a contrastive way on a large dataset of multi-temporal homogeneous or heterogeneous image patches. Finally, the feature distance between the outputs of the two branches is used to define a change measure, which can be analyzed by thresholding to get the final binary change map. Experiments are carried out on five homogeneous and heterogeneous remote sensing image datasets. The proposed SSL approach is compared with other supervised and unsupervised state-of-the-art change detection methods. Results demonstrate both improvements over state-of-the-art unsupervised methods and that the proposed SSL approach narrows the gap between unsupervised and supervised change detection.**

***Index Terms*—Change Detection, Self-supervised Learning, Multi-view, Sentinel-1/-2, Remote Sensing.**

## I. Introduction

CHANGE maps are one of the most important products of remote sensing and are widely used in many applications including damage assessment and environmental monitoring. The spatial and temporal resolutions play a crucial role in obtaining accurate and timely change detection maps from multi-temporal images. In this context, irrelevant changes, such as radiometric and atmospheric variations, seasonal changes of vegetation, and changes in the building shadows, which are typical of multi-temporal images, limit the accuracy of change maps.

In the past decades, many researchers developed techniques that directly compare pixels values of multi-temporal images to get the change maps from coarse resolution images [1]–[3], assuming that the spectral information of each pixel can completely characterize various underlying land-cover types. Image rationing and change vector analysis (CVA) [2] are early examples of such algebraic approaches. With the development of remote sensing satellite technology, the spatial and spectral resolutions of remote sensing images have significantly increased. In this context, the use of spectral information only is often not enough to distinguish accurately land-cover changes. Accordingly, the joint use of spatial context and spectral information to determine the land-cover changes has gained popularity. Many supervised [4] and unsupervised [5] techniques have been developed in this context. Most of them are based on image transformation algorithms where the crucial point is to obtain robust spatial-temporal features from multi-temporal images. Recently, deep learning techniques and in particular Convolutional Neural Networks (CNNs) methods [6] have been widely used in this domain. CNNs allows one to get effective and robust features for the change detection tasks, achieving state-of-the-art results in a supervised way [7].

Most of the past works are limited to the use of single modality images that are acquired by the same type of sensor with identical configurations. Cross-domain change detection has not received sufficient attention yet. Current Earth Observation satellite sensors provide abundant multi-sensor and multi-modal images. On the one hand, images taken by different types of sensors can improve the time resolution thus satisfying the requirement of specific applications with tight constraints. A possible example of this is the joint use of Sentinel-2 and Landsat-8 images for a regular and timely monitoring of burned areas [8]. However, the differences in acquisition modes and sensor parameters present a big challenge for traditional methods. On the other hand, multimodal data are complementary to the use of single modality images and their use becomes crucial especially when only images from different sensors are available in some specific scenarios. This could be the case of emergency management when, for example, optical and SAR images could be jointly exploited for flood change detection tasks [9]. In this scenario, methods capable of computing change maps from images of different sensors in the minimum possible time can be very useful. This has led to the development of multi-source change detection methods, which can process either multi-sensor or multi-modal images.

Recent success of deep learning techniques in change detection is mainly focused on supervised methods [10]–[12], which are often limited from the availability of annotated datasets. Especially in multi-temporal problems, it is expensive and often not possible to obtain a large amount of annotated samples for modeling change classes. Thus, unsupervised methods are preferred to supervised ones in many operational applications. The limited access to labeled data has driven the development of unsupervised methods, such as Generative Adversarial

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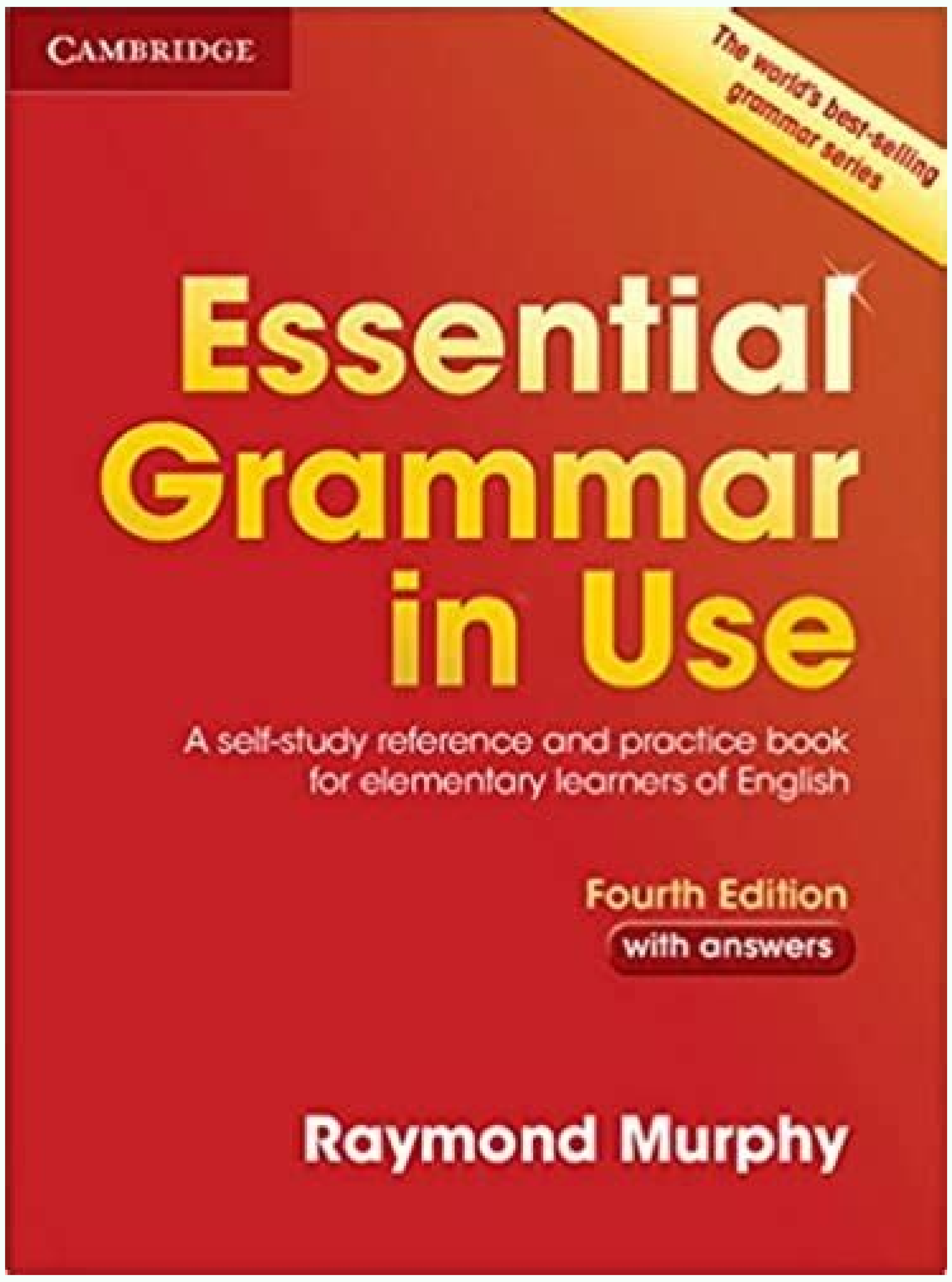


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# Learning from Scale-Invariant Examples for Domain Adaptation in Semantic Segmentation

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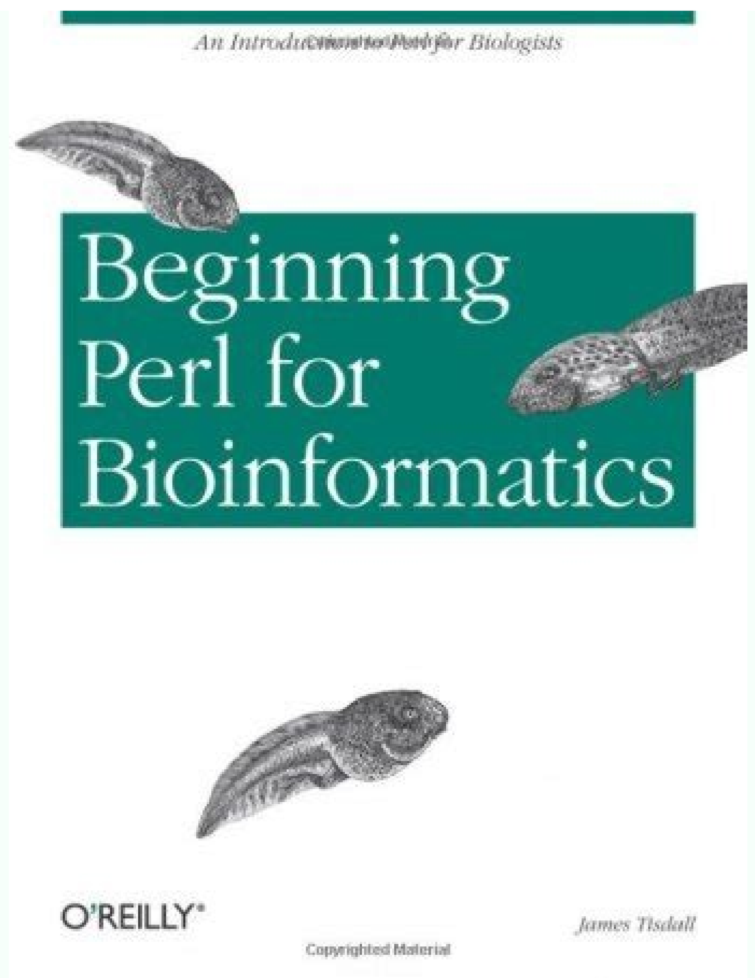
**Abstract.** Self-supervised learning approaches for unsupervised domain adaptation (UDA) of semantic segmentation models suffer from challenges of predicting and selecting reasonable good quality pseudo labels. In this paper, we propose a novel approach of exploiting *scale-invariance property* of the semantic segmentation model for self-supervised domain adaptation. Our algorithm is based on a reasonable assumption that, in general, regardless of the size of the object and stuff (given context) the semantic labeling should be unchanged. We show that this constraint is violated over the images of the target domain, and hence could be used to transfer labels in-between differently scaled patches. Specifically, we show that semantic segmentation model produces output with high entropy when presented with scaled-up patches of target domain, in comparison to when presented original size images. These scale-invariant examples are extracted from the most confident images of the target domain. Dynamic class specific entropy thresholding mechanism is presented to filter out unreliable pseudo-labels. Furthermore, we also incorporate the focal loss to tackle the problem of class imbalance in self-supervised learning. Extensive experiments have been performed, and results indicate that exploiting the scale-invariant labeling, we outperform existing self-supervised based state-of-the-art domain adaptation methods. Specifically, we achieve 1.3% and 3.8% of lead for GTA5 to Cityscapes and SYNTHIA to Cityscapes with VGG16-FCN8 baseline network.

## 1 Introduction

Deep learning based semantic segmentation models [29,3,32,31] have made considerable progress in last few years. Exploiting hierarchical representation, these models report state-of-the-art results over the large datasets. However, these models do not generalize well; when presented with out of domain images, their accuracies drops. This behavior is attributed to the shift between the source domain, one over which model has been trained, and target, over which its being tested. Most of semantic segmentation algorithms are trained in a supervised fashion, requiring pixel-level, labor extensive and costly annotations. Collecting such fine-grain annotations for every scene variation is not feasible. To avoid this pain-sticking task, road scene segmentation algorithm use synthetic but photo-realistic datasets, like GTA5 [20], Synthia [21], etc., for training. However, they

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Who should read the book: While the book is aimed at beginners, with no coding experience, it is also a handy guide for machine learning researchers and engineers. The book will also help sharpen knowledge about Regression Analysis, how to create trend lines, data scrubbing techniques and using Decision Trees to decode classification. The book also covers clustering techniques, largely used to build machine learning models for price predictions using Python, as well as artificial neural networks. Machine Learning for Beginners: By Scott Chesterton A veteran of over half a dozen books on machine learning, Scott Chesterton brings together the basic aspects of machine learning in this book, such as popular machine learning frameworks being used, machine learning algorithms, evaluation systems, data mining, and other common applications of machine learning. The book features commentaries on machine learning software such as TensorFlow, Reptilian, Logstash, Installation of Marvel, Bro, HDFS, HBASE, Syslog, SNMP, messaging layer and real-time processing layer. Who should read the book: Essentially for beginners, the book covers key concepts such as data preparation, data set cleaning, classification, testing, induction and deduction, inductive preference, overfitting and underfitting, and text data extraction. Beginners interested in machine learning will also be able to learn key algorithms such as Decision Tree, Openers, DBSCAN, Knowledge Mapping, Linear Models, K-Nearest Quartieri, carrier support machine (SVM), FP-Growth and the new wave in ML – neural networks and popular neural convolutional network algorithms along with their practical applications. Read more: What is machine learning? Hands-On Machine Learning with Scikit-Learn, Keras and TensorFlow: concepts, tools and techniques for the construction of intelligent systems by Aurelien Geron One of the most read books in artificial intelligence and machine learning space, this practical guide by Aurelein Geron is a must-read for data scientists and machine learning enthusiasts looking for practical examples on how to implement ML tools. Who should read the book: The book is addressed to readers who have experience of Python coding. The book introduces readers to a series of techniques, ranging from simple linear regression to deep neural networks, for the construction of intelligent systems on popular Python structures such as Scikit-Learn, Keras and TensorFlow. Readers can also learn how to form models such as support vector machines, decision trees, random forests and ensemble methods work. The main prerequisite before buying this book is to have a background in Python. Python Data Analytics: With enigammi enigammi ,aidem laicos ied isilana us ehcincet el ereilgoccar id odarg ni onnaras irotappulivs ilG .elaer odnom led imelborp a enoizacilppa'l rep elitu illeN oibaF id orbil otseuq onnarevort nohtyP id esab id enoisnerpmoc anu onnah ehc oroloC illeN oibaF id biltolptaM e yPmuN with OpenCV and libraries for deep learning. The book offers more examples of how Python can be used for data processing, management and information recovery. It also gives a look at the popular deep learning libraries such as Pytorch, Tensorflow, Keras and Theano. Who should read the book: for young data scientists and developers with knowledge of Python, this book offers the opportunity to learn how to distribute Python tools and techniques and use libraries such as Numpy, Matplotlib and Scikit-Learn for data analysis, data visualization, data visualization and scientific calculation. Further information: 10 Best 2020 Auto Learning Projects Five Best Auto Learning Books For Intermediate Artificial Intelligence and Auto Learning for Scott Chesterton Businesses This book by Scott Chesterton is not a long reading or could contain examples of advanced coding, but it acts as a good theoretical resource on how to make AI and ML projects operational, such as ML tools and techniques can be used best to process big data and how to display the analytical results of predictive models. The book is aimed at intermediate-level users who are familiar with automatic learning tools, frameworks and techniques. Who should read the book: This book will be more useful for machine learning engineers and organizations analysis managers who are looking to develop new AI and ML projects to stimulate business growth or build their business strategy. Through this book, Chesterton introduces readers to machine learning projects and how they can be used to improve organizations' skills and competitiveness and how automated learning teams can prepare themselves anihccam anihccam al onocudnoc e onodnerppa enihccam el emoc id enoisnerpmoc al ,ocitamotua otnemidnerppa'llus itnaipicnirp i rep inoizamrofni etlom onatneserp ztnaL tterB id orbil led ilaizini ilotipac i ertnem ztnaL tterB id )avittiderp enoizalledom al rep itrepse id ehcincet( R noc ocitamotua otnemidnerppa'L .alacs atsav us ocitamotua otnemidnerppa'l onocsiubirtsid is odnauq edifs evoun With R, the narrative graduates soon to more technical aspects with information on practical applications. Lantz also offers useful suggestions such as the generalization of tabular data structures with typs, accelerating and simplifying the preparation of data with DPLER, reading and writing on external data files, working with online data services, analyzing XML and JSON documents from WEB API , manage very large data sets, using very large data sets, using very large data sets, using very large data sets, using very large data sets, using very large data sets, using i Very large data set, using very large data sets, using very large data sets, using very large data sets, using very large data sets, using massive matrices with bigmemory, conducting parallel cloud computing, distribution of optimized learning algorithms and perform the GPU calculation. Those who should read the book: data engineers and analysis teams can refer to the book to know the regression methods to predict numerical data, apply linear regression to predict medical expenses and evaluate and improve model performance. The algorithmic leader: how to be intelligent when the machines are more intelligent by Mike Walsh, while it is not really a tutorial on algorithms, framework or automatic learning techniques for the well -known futuristic Mike Walsh is a practical guide for the leaders of the Sector, business leaders and IT decision makers. The book contains 10 principles of achievement of success in the algorithmic era and these lessons are eliminated from cases study and interviews with artificial intelligence pioneers, expert scientists and corporate leaders. Who should read the book: company leaders and veterans in the sector can use the book to understand And the future of concepts such as decentralization, digital interruption, probabilistic thought, ethics and automatic learning and learning to use these concepts for purposes to solve and make decisions. It also can be used as a practical guide for the laying of roadmaps for new generation technologies in organizations. Further information: 5 programming languages for beginners an introduction to statistical learning with applications in R (Springer texts in Statistics) this relatively recent book by Gareth James, James, elled otnemidnerppa'llus irbil iroilgim euqniC ?elarutan augnil alled enoizarobale'l ¨Ã'soc ehC :¹Ãip id enrepas reP .ehcitarp inoizapuccoerp el eratnorffa rep orevop olledom led inoizatserp elled esuac elled enoizinifed al e ,irottiderp ied enoizeles al ,essalc id oirbiliuqs olled enoitseg al erecsonoc id odarg ni ehcna onnaras irottel I .R ecidoc oipma nu odnazzilitu itailgatted onos issecorp itseuQ .enredom enoizacifissalc e enoisserger id ehcincet ellus elaer ativ id inoizartsulli e etidnoforppa eton eneitnoc e itsinoisseforp e irotacrecir a otlovir ¨Ã orbil lI :orbil li ereggel ebbervod ihC .olledom led otnup a assem al e itad ied enoisivid al ,itad ied enoizarobaleerp al iuc art ,elareneg avittiderp enoizalledom id ossecorp li acric enoisnerpmoc anu erisiuqca rep odom nu 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