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STANDALONE SOFTWARE FOR DETECTING CHANGES IN SAR AND OPTICAL IMAGES

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ABSTRACT

Change detection is an important application in remote sensing earth observation which leads to identification of significant environmental events, forest and agricultural land monitoring. In this paper, we introduce a standalone software for two well-known change detection methods, omnibus test and iteratively re-weighted multivariate alteration detection (IR-MAD). Omnibus test deals with synthetic aperture radar (SAR) data and detects changes based on computing a sequence of test statistics of covariance matrices and IR-MAD computes the changes between two time points of optical data. Given the availability of earth observation data from different sources and in large amount, the important role of a free software which can deal with big data is apparent.

1. INTRODUCTION

This paper aims to introduce a standalone software for two automatic and popular change detection methods; Omnibus test [3, Sec 2.1] and iteratively reweighted multivariate alteration detection (IR-MAD) [7, Sec 2.2]. The standalone software is available in two formats i.e. graphical user interface (GUI) app and command-line executable. The app has an interactive user interface while the command-line version can be run directly on console given the specified variables (Sec 3). Moreover, the standalone software can handle different formats of images, such as Georeferenced Tagged Image File Format (GeoTIFF), and ENVI binary image coupled with a header file and it has a special module for big data. Depending on the memory capacity of the computer, users can choose to load images into memory or use line by line processing. Furthermore, to decrease the computation time, the software uses parallel computing techniques. For demonstration, two examples are considered using different formats of the software on SAR and optical images. The software is published on github.com/BehnazP/DataBio.

2. METHODS

In this section both change detection methods are briefly explained [for more detail see 3, 7]. Note that in the standalone software, omnibus test is called WISHARTChange and IR-MAD method is called MADChange.

2.1. WISHARTChange

Omnibus test [3] is a change detection method for a sequence of multi-look polarimetric synthetic aperture radar (SAR) data [9]. The method applies a test statistic to quantify the equality of polarimetric covariance matrices ($\mathbf{\Sigma}_{p\times p}$). Detecting if and when a change has occurred is based on the test statistics' significance level on a per-pixel basis or collections of pixels (segments, patches, fields) .

The equivalent number of looks (ENL) in SAR imagery refers to the number of independent pixels of a surface area that is averaged in order to reduce the effect of speckle. Speckle is a noise-like consequence of the coherent nature of the signal transmitted from the sensor. The main assumption of the WISHARTChange method is that the multiplication of the observed signals ($\mathbf{\Sigma}$) by ENL (n), are complex Wishart distributed, i.e. $\mathbf{X} = n\mathbf{\Sigma} \sim W_C(p, n, \mathbf{\Sigma})$.

The method tests a hypothesis that all pixels from different time points ($t \geq 2$) are characterized by the same $\mathbf{\Sigma}$. Therefore the null hypothesis is $H_0 : \mathbf{\Sigma}_1 = \mathbf{\Sigma}_2 = \cdots = \mathbf{\Sigma}_T (= \mathbf{\Sigma})$ against the alternative (H_1) that at least one of the $\mathbf{\Sigma}_t, t = 1, \ldots, T$, is different, i.e., at least one change has occurred. Since the distributions are known, a likelihood ratio test can be formulated which allows one to decide a desired level of significance whether or not to reject the null hypothesis. The algorithm computes the logarithm of the omnibus likelihood ratio test statistic, Q, for testing H_0 against H_1 (see [3] for more detail).

Furthermore, this test can be factored into a sequence of tests involving hypotheses of the form $\mathbf{\Sigma}_1 = \mathbf{\Sigma}_2$ against $\mathbf{\Sigma}_1 \neq \mathbf{\Sigma}_2$, $\mathbf{\Sigma}_1 = \mathbf{\Sigma}_2 = \mathbf{\Sigma}_3$ against $\mathbf{\Sigma}_1 = \mathbf{\Sigma}_2 \neq \mathbf{\Sigma}_3$, and so forth. The method computes the likelihood ratio test statistic R_t for testing the hypothesis $H_{0,t} : \mathbf{\Sigma}_t = \mathbf{\Sigma}_1$ against $H_{1,t} : \mathbf{\Sigma}_t \neq \mathbf{\Sigma}_1$. The R_t constitute a factorization of Q such that $Q = \prod_{t=2}^{T} R_t$.

The tests are statistically independent under the null hypothesis. In the event of rejection of the null hypothesis at some point in the test sequence, the procedure is restarted from that point, so that multiple changes within the time series can be identified.

2.2. MADChange

Iteratively reweighted multivariate alteration detection (IR-MAD) algorithm [7, 1] is a statistical approach to detect

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changes in optical images. This method utilizes an iteration scheme to identify a better background of no-change against which to detect significant change. The method applies canonical correlation analysis (CCA) [6] to multi-spectral images from two time points. The CCA orders the image bands according to similarity based on correlation, rather than spectral wavelength. The differences between corresponding pairs of canonical variates are called the MAD variates,

$$\mathbf{Z} = \mathbf{a}^T\mathbf{X} - \mathbf{b}^T\mathbf{Y}$$

where $\mathbf{X}$ and $\mathbf{Y}$ represents the m-dimensional images, and $\mathbf{a}$ and $\mathbf{b}$ are the eigenvectors from the CCA. Therefore, $\mathbf{a}^T\mathbf{X}$ and $\mathbf{b}^T\mathbf{Y}$ are m uncorrelated canonical variates (CVs) with mean zero and variance one for time points one and two, respectively. The correlation between corresponding pairs of CVs, the canonical correlation ($\boldsymbol{\rho}$) is maximized in CCA, therefore we have m uncorrelated MAD variates with mean zero and variance $2(1-\boldsymbol{\rho})$. Since the MAD variates for the no-change observations are approximately Gaussian and uncorrelated, the sum of their squared values after normalization to unit variance ideally follows a chi squared distribution with m degrees of freedom,

$$C^2 = \sum_{i=1}^{m} \frac{Z_i^2}{2(1-\rho_i)} \sim \chi^2(m).$$

In addition the probability of no-change is approximated by $1 - \mathsf{P}\{\chi^2(m) \leq c^2\}$ where c^2 is the actually observed value of C^2 and used as weight, w. In each iteration the value of each image pixel is weighted by corresponding w which is the current estimate of the no-change probability and the image statistics i.e. mean and covariance matrices are recomputed. Iterations continue until the canonical correlations stop changing according to a pre-defined threshold or a maximum number of iterations is reached.

3. STANDALONE SOFTWARE

The standalone GUI app and command-line program for both WISHARTChange and MADChange methods are developed in MATLAB®. At the time of writing the manuscript, the software packages are available for Windows and Linux operating systems. The Mac version is under development.

Depending on memory capacity of the user's computer, the software can handle small and big images by either fitting them into local memory or reading and treating them line by line. The uniqueness of the standalone software is the ability of dealing with different types of image such as GeoTIFF and ENVI, i.e. a flat-binary raster file with an accompanying ASCII header file. For cloud based software working with Google Earth Engine (GEE) [5] see [2] and for MATLAB based packages for specific image type, see [4] for IR-MAD and see [8] for omnibus test.

3.1. Download and installation

Users can download the GUI app and command-line version of the software from github.com/BehnazP/DataBio and install it on their computer. In order to use the standalone software, first the MATLAB Runtime installer provided with the software should be installed. The installer contains all the required MATLAB functions for running the software *without* having MATLAB installed on the user's computer.

The GUI app can run similar to any other software after installation. For executing the command-line version on Windows, users go to the directory of the saved executable file and call the executable and provide the input variables. Linux users, in addition, have to provide the path to installed MATLAB Runtime following the executable file.

3.2. Input

In WISHARTChange, users are required to provide sequence of SAR images, processing modality to read the images into the memory or using the line by line processing, ENL, p-value significance level for the omnibus test, polarization type, number of time points, polarization names as well as the name used for time sequences, saving directory. In addition, there is an option to select and compute the changes in a region of interest (ROI) by providing a binary mask or by choosing the ROI interactively from the frequency map (see Fig. 2 a.).

In MADChange, users are required to provide the two multi-spectral optical images, the name of the multi spectral bands used in the name of the images, a threshold as a criterion to stop the iteration, processing modality to read the images into the memory or using the line by line processing, and saving directory for the results. In addition, there are two options to do a pre-processing scheme by masking the strongest changes and excluding low values related to dark regions [4].

Note that, if users do not provide any extra information except the input images, the app will apply the method based on default values pre-defined in the software.

3.3. Output

The WISHARTChange software outputs a table containing average no-change probabilities and a figure containing maps of changes. In addition, the table is saved as a text file and the maps are saved as an image with three bands, i.e. first change, last change and frequency of the change in same format as the provided images.

The MADChange software outputs a figure showing the probability of no-change. Moreover, the IR-MAD variates are saved for further analysis as an image with same number of bands and same format as the provided images. In addition, there is an option to save the CVs and chi-square images. The software also provides the canonical correlation convergence plot.

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3.4. Illustration

In this section, we include two examples using MADChange and WISHARTChange standalone software for visualisation of results and outputs.

In the first example, the WISHARTChange software is applied to SAR data which are acquired by the fully polarimetric Danish airborne SAR system, i.e EMISAR (see [3] for more detail). The example investigates the changes in crops land and forest area of Foulum in Jutland Denmark for six time points; March 21, April 17, May 20, June 16, July 15, and August 16, 1998. The identified changes can help environmental managers to study the development stage of different crops and forest areas. Fig 1 shows first change, last change and the frequency of the change which occurred in the area. For demonstration, a region of interest (ROI) is chosen interactively (Fig 2 a.) and the probability of no-change is computed and shown in Fig 2 b. The chosen ROI is a peas farm land and from the results one can conclude there has been significant changes between all six points.

In the second example, the MADChange software is applied to GeoTiff data which is obtained from GEE. The example investigates the changes in agricultural land and forest areas of Javier in North Spain for two time points; October 21 2016 and October 11 2017. The identified changes can help forest managers and land owners to identify forest disease and monitor the changes in their lands in early stages. Fig 3 shows the probability of no-change in the Javier region. The first three bands of IR-MAD variates is shown in Fig 4 as a RGB image corresponding to greatest canonical correlation. The figures indicate no-change in forest area, small changes in some of the grass lands around agricultural areas and major changes in agricultural land.

4. CONCLUSION

This paper introduces standalone software for SAR and optical images which can be used in many application areas where analysing and monitoring spatio-temporal dynamics is important. The software packages are called WISHARTChange and MADChange and are based on two automated and popular change detection methods; omnibus test and IR-MAD, respectively. The software is published on github.com/BehnazP/DataBio in two versions; GUI app and command-line executable. The uniqueness of the standalone software is its flexibility to handle different formats of images and also its capability to handle big data.

The outputs of the standalone software are shown in two examples. The results provide insights for detecting changes that might help environmental managers and policy makers.

5. ACKNOWLEDGEMENT

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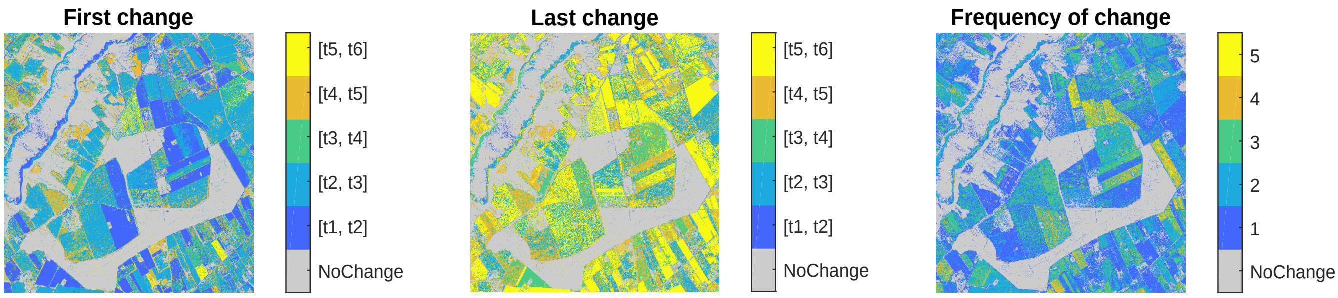
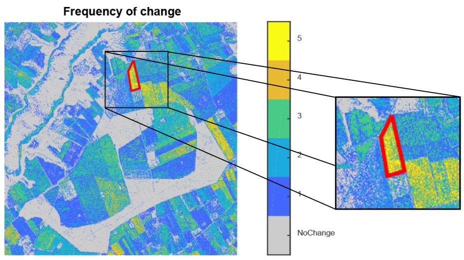


Fig. 1. Output from WISHARTChange software for the Foulum area in Denmark for six time points, on the left is the map of first changes, middle is the map of last changes, and the right shows the frequency of the changes.



a. Peas farm land

P-values

	t1 = ... = t6	t2 = ... = t6	t3 = ... = t6	t4 = ... = t6	t5 = t6
Omnibus	0	0	0	0	1.0000e-05
t1 = t2	0.0008	NaN	NaN	NaN	NaN
t2 = t3	0.0035	0.0036	NaN	NaN	NaN
t3 = t4	0	0	0	NaN	NaN
t4 = t5	0	0	0	0.0050	NaN
t5 = t6	0.0018	0.0015	4.9000e-04	0.0001	1.0000e-05

b. Averaged no-change probabilities

Fig. 2. Output from WISHARTChange software; a. shows the region of interest chosen interactively and b. shows the average no-change probabilities for the peas farm land selected in a).

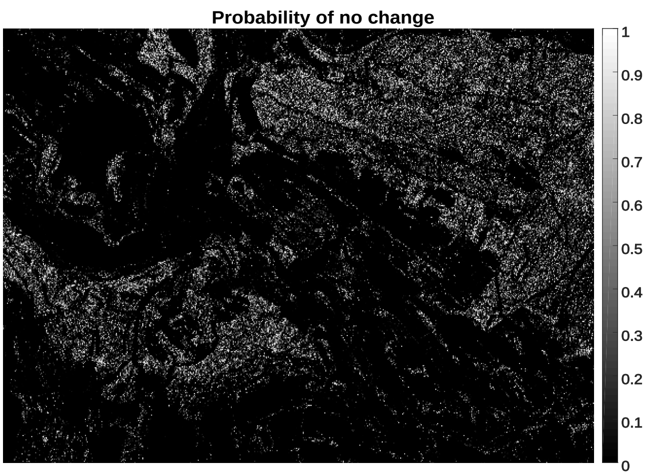


Fig. 3. Output from MADChange software showing probability of no change in Javier region in North Spain between October 21 2016 and October 11 2017.

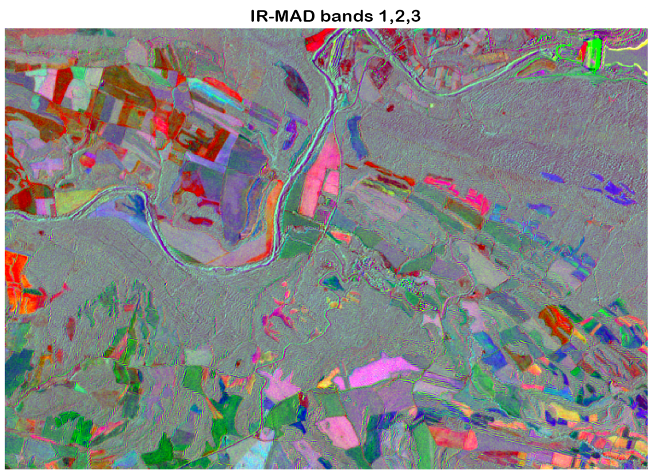


Fig. 4. The image of first three IRMAD variates show different changes in agricultural lands, forest areas and grass lands based on the output from MADChange software.

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