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EXPLORING AN UNSUPERVISED DATA MINING APPROACH TO EXTRACT ASEISMIC SLIP EVENTS ALONG THE IZMIT SECTION OF THE NORTH ANATOLIAN FAULT, BASED ON FLATSIM TIME SERIES

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The North Anatolian Fault (NAF) is known for hosting large earthquakes, but also continuous or transient aseismic slips. Sentinel-1 (S1) InSAR time series analyses revealed the occurrence of several transient aseismic slip events (or bursts of creep) since 2014 [1, 2] along different sections of the fault. More systematic detection and characterization of their spatio-temporal characteristics are essential to better understand their physical mechanisms and their potential impact on seismic hazard.

Here, we use S1 InSAR time series along the Izmit section of the NAF, automatically processed by the FLATSIM service [3], to test an unsupervised spatio-temporal data mining approach [4] (DFTS-P2MINER prototype available at <https://sites.google.com/view/dfts-p2miner>) to automatically detect in time, and locate in space, creep events.

The aim of this unsupervised process is to extract from the InSAR time series pixel evolutions/sub-evolutions, such that the pixels affected by a pixel evolution cover a minimum surface and are sufficiently connected to each other. A pixel evolution is a sequence of pixel states, where these states are discrete values encoding the amplitude and sign of the displacements in the satellite line of sight. The extracted evolutions are the patterns of interest and can be depicted on maps, where the spatial information is given by pixel positions while the temporal information is displayed using color palettes. In this study, we rely on two key parameters of this evolution mining approach to extract aseismic slip events. The first parameter is the minimum surface threshold that ensures that the evolutions reflected by the patterns cover a sufficient area. The second one is a connectivity threshold that guarantees the local spatial coherence of the patterns.

We first work on synthetic displacement time series of 25 images covering 261 x 195 pixels and containing one shallow

burst of creep superimposed with realistic, spatially correlated InSAR-type noise with characteristics similar to the one of real time series in the area. In the cumulated displacement maps, positive (resp. negative) values correspond to motion away from (resp. towards) the satellite. Each map at each time step is discretized using equal frequency bucketing in three levels. These levels represent relative surface displacements across and along the fault (1: strong motion towards satellite, 2: small motion considered as neutral, 3: strong motion away from the satellite).

We first show that a simple workflow allows to detect specific spatial patterns corresponding to the synthetic burst, as well as to pick the beginning and end of the transient event in time. We then apply the methodology to a real time series [5] with similar temporal length and pixel number. This series is composed of 25 cumulated displacement images (202 x 202 pixels) covering an area of about 17 km x 5 km of the Izmit section of the NAF, at the end of year 2019 including a known creep event [5]. The first results appear promising. Spatial patterns likely related to the 2019 burst are clearly identified on both sides of the fault. They are consistent with contours and signs of maximum cumulated displacement previously measured (Fig. 1). We also compare the temporal evolution of the relative displacement of pixels on both sides of the fault, selected near the fault and within the detected « burst spatial patterns », to that computed from a model prediction of the 2019 burst [5] (Fig. 2). This evolution does show the burst despite noise, at the location automatically detected by DFTS-P2MINER, with a creep step across fault consistent with the model.

Future steps will include, based on various sets of synthetic time series, an exploration of the limits of the detection method in terms of signal to noise ratio, which depends in particular on the depth, size and longitudinal extent of the burst events.

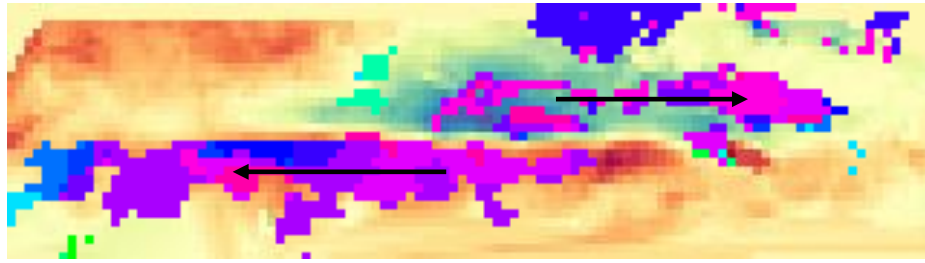


Figure 1. Colored patterns show displacement patterns with strong motion toward west south of the fault and strong motion toward east north of the fault, detected by DFTS-P2MINER, superimposed on cumulated displacement map from InSAR time series analysis from [5], corresponding to the 2019 creep burst. Colors encode dates and can be used to estimate the burst period.

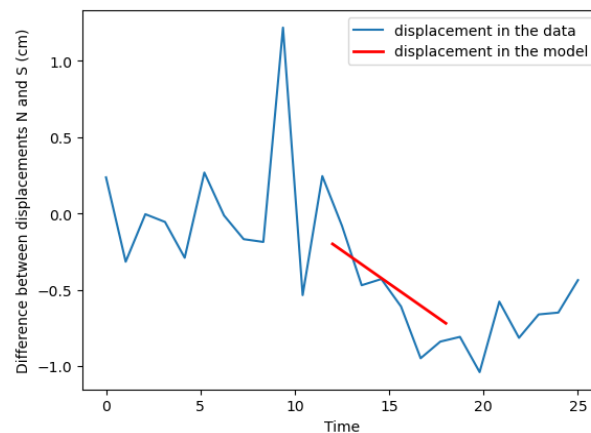


Figure 2. In blue: Temporal evolution of the relative displacement of two pixels on both sides of the fault, selected near the fault and within the « burst spatial patterns » detected by DFTS-P2MINER. Red line shows the creep change modeled in [5].

Index Terms— InSAR, Data mining, Tectonic deformation, Spatio-temporal pattern, Satellite image time series.

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