Trajectory analysis of multi-temporal satellite images for monitoring grassland dynamics

PhD thesis proposal

The PhD aim is to exploit time-series of images acquired by the latest generation of Earth Observation sensors for the characterization of agricultural environments. The high spatial and temporal resolutions and the complementarity of the new optical and radar sensors allow both a relatively accurate crop delineation and semantization. The analysis of these dense times series offers new opportunities to monitor and characterize land cover/use changes. Accordingly, this research is focus on the **trajectory analysis of these multi-source image time series covering multiple years to study grassland areas both in supervised and unsupervised ways**. Specifically, the main goal is to characterize seasonal and long-term trends, as well as abrupt changes and anomalies so as to detect human activities. The interleaved applications are two-fold: (i) monitoring human activities that are subject to highly controlled rules and European fundings ; (ii) improving crop classification systems that exhibit low performances for grasslands.

Context

Remote sensing offers the possibility to provide information on landscapes over large scales, thanks to the large spatial coverage and regular revisit frequency of spaceborne sensors. Radar and optical images time-series have already proved to be invaluable and complementary inputs for monitoring land cover/use changes in vegetation and cropland areas. Such relevance assessed with MODIS sensor in the 2000s has been recently exacerbated with the launch of the new Sentinel constellation and missions dedicated to specific environments (such as VenµS for vegetated areas), as well as the spread of free and open policies for the distribution of satellite images (Landsat, Copernicus, Spot World Heritage).

In agricultural environments, grasslands are a land cover class of crops of utter interest since they provide many ecosystem services such as quality feed, animal health or quality biomass (Si et al., 2012; Socher et al., 2013; Lopes et al., 2017). Accordingly, grasslands are frequently affected by human activities (e.g., moving, grazing, (Li et al., 2013; Dusseux et al., 2014)), and subsequently are highly controlled for regulation and European funding issues (Common Agricultural Policy, see (Kleijn & Sutherland, 2003)). Their characterization and discrimination have been barely investigated in the literature (Gómez Giménez et al., 2016). Recent works and large scale experiments in several European countries (Ukraine, Czech Republic, Germany) have highlighted the challenges of such a difficult task : the spatial heterogeneity, the distinct phenological cycles, and various anthropogenic interventions should be careful considered and discriminated (Lopes et al., 2017; Stenzel et al., 2017). Existing literature has demonstrated that time series of images (Dusseux et al., 2014; Lopes et al., 2017) are particularly suited for detecting grasslands and documenting human activity, especially in a multi-modal context (Hadria et al., 2009). However, they remain limited to very few epochs (Gómez Giménez et al., 2017) while dense datasets are more beneficial, especially with multiple points of view and very high spatial resolution (Schuster et al., 2015). To top it all, when grassland delineation is at stake, agricultural practices are ignored or

implicitly handled and when anthropogenic events are detected, existing and accurate grassland maps are available (Hadria et al., 2009; Esch et al., 2014), **while both issues are strongly interleaved.**

The analysis of satellite image time-series can be roughly divided in two main categories of approaches:

- *Classification approaches* : based on ad-hoc features (commonly, spectral indices) on a yearly/multi-year basis or composite images, both supervised and semi-supervised approaches are possible (Flamary et al., 2015). The main challenge consists in dealing with the high variability in the signals (within a year, between years) and with abrupt changes (Dusseux et al., 2014). Performances can be boosted by incorporating knowledge extracted from the time series or external sources, such as farmer annual declarations for the case of crop monitoring (Bailly et al., 2017).
- *Modeling approaches* : they aim to capture the inter-annual and intra-annual variations and identify changes in the phenological patterns. They require dense datasets. They are perfectly tailored for (almost real-time) event detection but assume already focusing on the class of interest. The literature mostly tackled the easier case of forests where parametric models can be fitted with few constraints (Lu et al., 2013; Dutrieux et al., 2015). Very few papers have focused on grassland dynamics and, at a large majority, with limited spatial resolution (Wang et al., 2010; Li et al., 2013).

In the literature of grassland delineation or dynamics monitoring, either of these two categories is employed. Nevertheless, since both issues are interleaved, there is a need to propose a novel framework benefiting from the fruitful cooperation of discriminative and generative approaches.

Objectives

In this work, the main goal is the exploitation of dense optical and radar image times series such as Sentinel-2/-1 and Venµs for grassland monitoring (delineation and event detection) over large areas. Specifically, the work will be performed on intra-annual and inter-annual scales and it will focus on :

1) Proposing a methodology to detect and cluster (i) trend dynamics and (ii) abrupt changes exploiting the high spatial and temporal resolution of the new image times series.
2) Integrating such knowledge on a classification and event prediction tasks.
3) Exploiting the synergy of optical and radar measurement to monitor and characterize grassland areas.
4) Dealing with the curse of dimensionality caused by the large data volume.

Impacts

The output of the PhD work will be two-fold : determining (i) main existing behaviors for crop classes with an emphasis on grasslands and in a dual way (ii) the characterization of human intervention over grasslands.
The benefit of this pattern recognition step will be evaluated for the fine classification of grasslands and for the prediction of forthcoming anthropogenic events.

We target to exploit Sentinel 1+2 time series as well Venµs study sites over France and therefore demonstrate how we can foster information extraction from dense time series of images for characterizing anthropogenic events over agricultural environments. It perfectly complements the seminal work of Dusseux et al. (2014), where only sequences of limited length were available, and potentially could be applied on Spot World Heritage data. The comparison with patterns detected

over areas of interest out of France available both with Sentinel constellation and Venµs sensor would be of broader interest for more global understanding.

From a practical point of view, grasslands concentrate a lot of attention from the French Ministry of Agriculture and the French Paying Agency (ASP): grasslands correspond to a majority of the European subsidies and the above mentioned human activities are detected with poor performance in the current process (visual inspection of 4 Very High Resolution images per year).

Supervision and hosting

- Clément MALLET (Dr. HDR), Sébastien GIORDANO (Dr.) - IGN/LaSTIG lab. (Saint-Mandé, France);
- Silvia VALERO-VALBUENA (Dr.) - University Paul Sabatier, CESBIO (Toulouse, France);
- Gérard DEDIEU (Dr. HDR) – CNES/CESBIO (Toulouse, France).

The student will be hosted in IGN/LaSTIG lab. in Saint-Mandé and in UMR CESBIO, Toulouse (probable 50% time splitting). LaSTIG gathers 4 research teams with IGN researchers, engineers as well as University Paris Est research. The associated doctoral school is ED MSTIC (Mathématiques et Sciences et Technologies de l'Information et de la Communication) of University Paris Est.

The subject is proposed by CESBIO and IGN, which have already collaborated within the Scientific Expertise Center OSO (Occupation des Sols, led by CESBIO) of Theia Land Data Centre since 2013. OSO coordinates the research activities in France in EO image analysis for land-cover mapping. In particular, a PhD student (2014-2017) is currently being co-supervised between CESBIO and IGN on large-scale classification with Sentinel-2 images (Pelletier et al., 2016; 2017). Further joint methodological improvements have been already formulated in a 3-years project to be submitted to the ANR for the 2018-2020 funding program.
From an operational point of view, IGN starts investigating the potential of the CESBIO iota² framework from its numerous country-scale land cover mapping issues.

Support

Apart from the methodological and technical expertise of IGN and CESBIO researchers and engineers, the project is supported by the French Ministry of Agriculture and the French Paying Agency (ASP). They provide thematic expertise on the subject, direct access to existing annual farmers' declaration as well as ground truth on 85 control areas in France.

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