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THE MISSION OF THE BIOSENSE INSTITUTE: NEW TECHNOLOGIES IN AGRICULTURE

Abstract: Agriculture is facing enormous challenges. Not only does it have to provide enough safe food for the growing population, it also needs to leave a minimal environmental footprint and combat climate change. The available natural resources are limited and the conventional agricultural technologies do not provide sufficient means to address these challenges.

On the other hand, a number of key enabling technologies have matured in the recent decade, including nano and microelectronics, material science, remote sensing, communications, and artificial intelligence. However, although some of these technologies have already created a significant impact in various aspects of human life and wellbeing, they have not yet delivered their full impetus to the agrifood sector.

Agriculture needs to be optimized. More (higher quality) yields need to be produced with less inputs (water, fertilizers, labor, energy...) and with less risks (related to weather, pests, market conditions...). However, agriculture is a very complex biosystem, and its optimization presents a significant challenge as it requires full understanding of all underlying processes and their correlations. The first step in this process is to develop and deploy various sensors that will provide as much information as possible about the plant itself, the soil, atmospheric and meteorological conditions.

However, large amounts of sensing data *per se* do not offer necessary insights into complex processes in agriculture. To discover underlying interdependencies and to create actionable information from sensing data, multisensor data fusion, feature engineering, deep learning and big data analytics need to be deployed. As a results, sufficiently large sets of reliable data combined with AI algorithms have already proven their potential in optimizing agriculture.

Key words: *digital transformation, sensing technologies, artificial intelligence, agriculture*

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SENSING TECHNOLOGIES FOR AGRICULTURE

As the quality of any measure or action to be taken to optimize agriculture directly depends on the quality of input data, it is necessary to develop devices that will provide reliable, rapid and precise data of interest to agriculture, whether in-situ, proximally or remotely. However, no single technology or single operating frequency can provide the means to develop all needed sensors that will detect and measure various biological, physical and chemical properties and processes in the plant, the soil and its environment. To that end, a wide range of expertise needs to be combined, spanning from physics and biology to electrical engineering and materials science, with main research directions depicted in Fig. 1.

We develop molecular, optical, micro and nanofluidic, solid state, acoustic, photonic and nano and microelectronic sensing applications with the goal to enable sensing of previously unattainable parameters or provide solutions more accessible than the existing ones (e. g. faster, cheaper, smaller).

In addition, various remote sensing technologies, including thermal, microwave, terahertz, multispectral and hyperspectral imaging obtained from various sensing platform ranging from ground, through UAV to satellites,

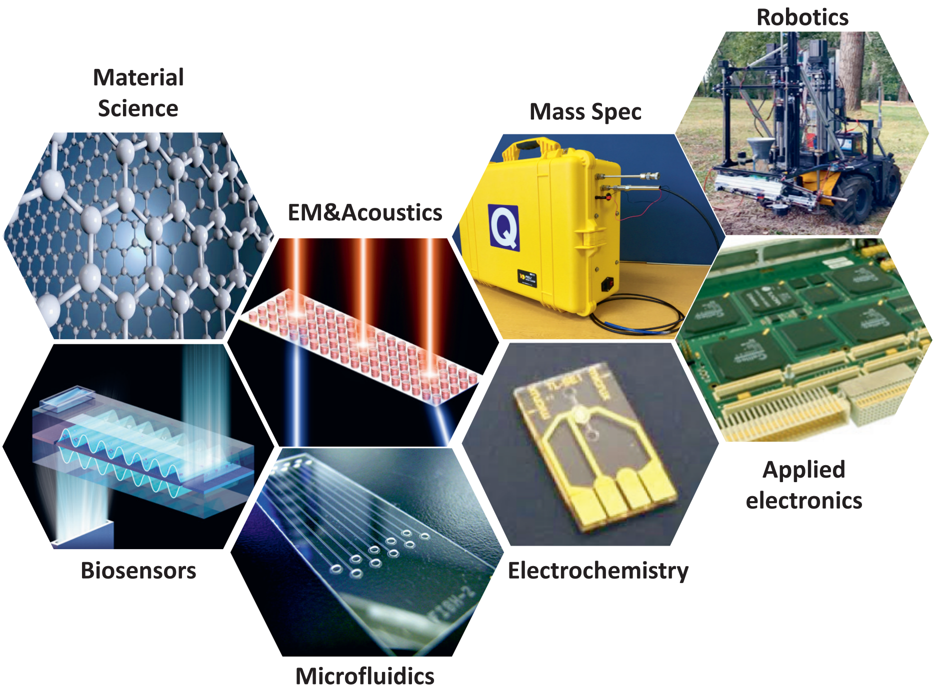

Figure 1. The core fields needed to develop necessary sensors for agriculture

enables us to discover qualitative and quantitative analytical data based on the interaction of electromagnetic radiation with living and non-living matter (e. g. NDVI, LAI, evapotranspiration, photosynthesis, etc.).

INFORMATION TECHNOLOGIES IN AGRICULTURE

To enable turning data into useful actionable information, research efforts across a number of directions in information technologies are needed that address challenges across the entire agri-food chain (from plant phenotyping, crop monitoring and yield prediction, to post harvest technologies, modelling, optimization and decision support). Fig. 2 depicts available data sources, technologies under development and final applications, all extremely relevant to agricultural applications.

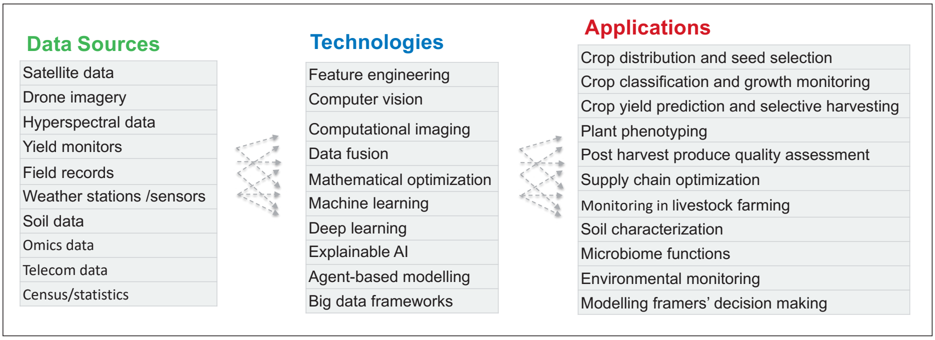

Figure 2. Interplay of data, information technologies and agricultural applications

For example, satellite technologies in combination with image denoising, CNNs and different algorithms such as Random Forest, are indispensable in application such as crop identification, Fig. 3, and crop monitoring, Fig. 4, including the detection of burnt farmland or irrigation optimization.

A number of challenges in agriculture require some sort of optimization, e. g. smart seed selection, optimsiation of seed distribution in retail, Fig. 5, vehicle routing problems etc.

The power of information technologies and the impact they have on the agricultural production can best be illustrated by the example of crop structure planning — one of the most common challenges in agricultural production. Namely, each year, a decision needs to be made on which crop to plant at which location to maximize profits, reduce yield and price risks, to obey to crop rotation, group crops to save fuel, and reduce the use of fertilizers and pesticides. On a farm of 6000 ha comprising of 70 fields grouped at 4 locations, where all five major crops are to be grown, the number of

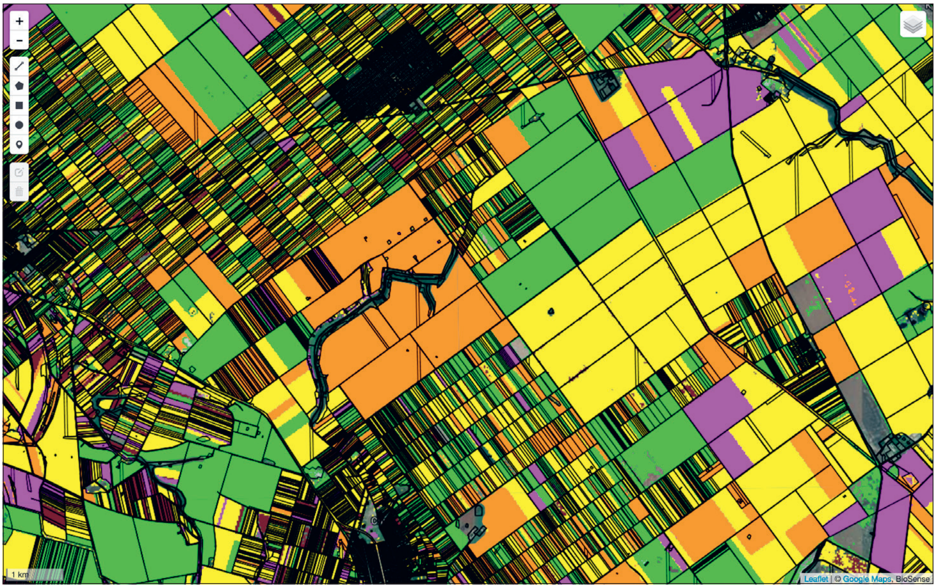

Figure 3. Satellite-based crop identification is West Balkans is burdened by very small size of plots (different colors denote different crop types identified with precision higher than 97%)

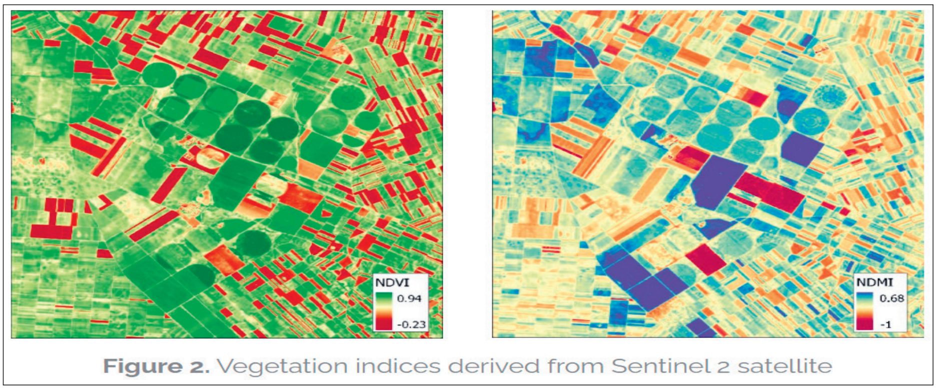

Figure 4. Satellite-based crop monitoring reveals health status of the plants (NDVI index).

crop combinations is around 10 quindecillion, far beyond the scope of any agriculture domain knowledge. By using AI-based crop structure planning solutions, with no additional investment whatsoever, increase of more than 60% in profits (with 10% reduction of compound risks) can be achieved, which, for a 6000 ha farm translates to additional profits of around 1.2 million € annually.

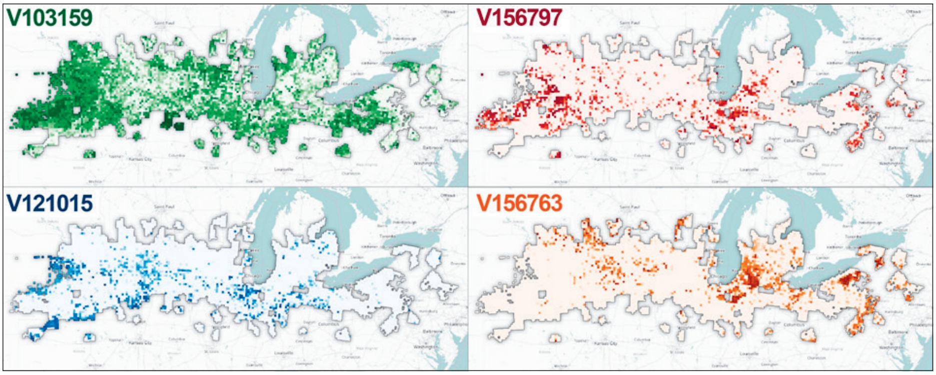

Figure 5. Optimal distribution of soy bean seeds in retail across the mid-west US

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MISIJA INSTITUTA BIOSENS: NOVE TEHNOLOGIJE U POLJOPRIVREDI

Sažetak

Poljoprivreda se suočava sa velikim izazovima. Ne samo da se od poljoprivrede očekuje da stvori dovoljno bezbedne hrane za rastuću svetsku populaciju, ona mora da ostavi minimalan ekološki otisak i izbori se sa uslovima klimatskih promena. Raspoloživi prirodni resursi su ograničeni i konvencionalne poljoprivredne tehnologije ne pružaju dovoljno mogućnosti za rešavanje ovih izazova.

Sa druge strane, u poslednjoj deceniji sazrele su brojne tehnologije, kao što su nano i mikroelektronika, nauka o materijalima, daljinska detekcija i veštačka inteligencija. Iako su neke od njih imale značajan uticaj na različite aspekte ljudskog života i blagostanja, ove tehnologije još uvek nisu ostvarile svoj puni potencijal u sektorima poljoprivrede i hrane.

Poljoprivredna proizvodnja se mora optimizovati, u smislu da je neohodno dostaviti veće i kvalitetnije prinose sa manje uloženih resursa (vode, đubriva, rada, energije...) i uz smanjenje rizika (vezanih za vremenske prilike, štetočine, tržišne uslove...). Međutim, poljoprivredna proizvodnja je u suštini veoma složen biosistem, a njena optimizacija predstavlja velik izazov, jer zahteva potpuno razumevanje svih fundamentalnih procesa i njihovih korelacija. Prvi korak u postupku optimizacije je stoga razvoj i upotreba različitih senzora koji će pružiti što više informacija o samoj biljci, zemljištu, atmosferskim i meteorološkim uslovima.

Ključne reči: digitalna transformacija, senzorske tehnologije, veštačka inteligencija, poljoprivreda