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XXXVII Cycle

Non-destructive Evaluation of Food Products by Microwave and mmW Imaging

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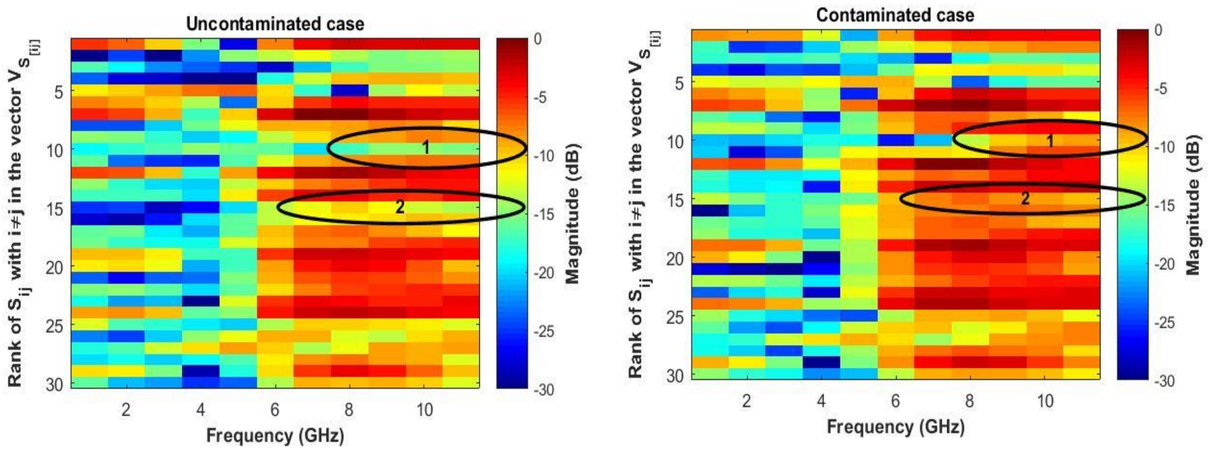
Research context and motivation

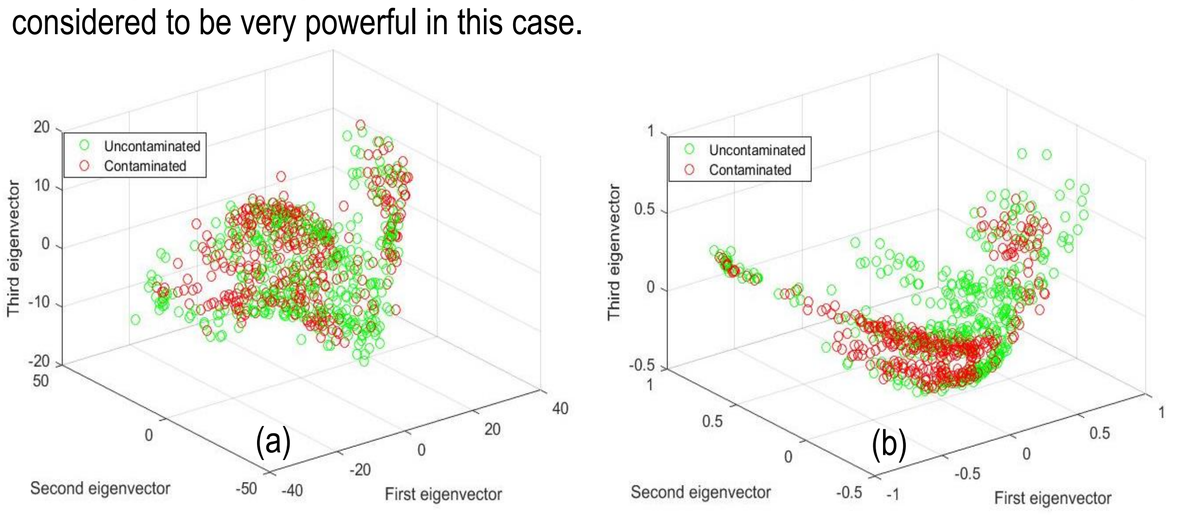
- The food industry, with its large-scale production lines and the growing need for traceability, is faced with the problem of automatic quality control of the products it supplies. One of the major challenges is the implementation of a non-destructive testing system capable of processing a large volume in real-time in order to remove damaged products from the chain. In practice, we are looking for defects, such as stains on fruit, or the presence of foreign object debris (FOD) in packaged products (small inclusions of glass, plastic, etc.).
- In recent years, many technologies were investigated and developed to overcome the intrinsic drawbacks of the currently employed techniques like (X-rays, metal detector), and to offer more appropriate solutions with respect to techniques developed in the academic domain in terms of acquisition speed, cost, and the penetration depth (infrared imaging).
- Microwave and millimeter imaging, because it is non-invasive and harmless, allows for compact, inexpensive systems while ensuring good penetration into materials. It is a very promising technique for these applications although it is still little explored.

Results

- The images shown below represent the plotting of the entire elements of matrices each of dimension 30 × 11, which is a set of information that carries the amplitude part only from the data measurements. The two images represent two jar samples under test, one is the uncontaminated sample, and the other stands for the contaminated one.



- The images contain relevant information, however, it is not enough for us as humans to determine if the image referred to a contaminated or uncontaminated jar sample.
- The usage of ML algorithms to automate the classification process is necessary and considered to be very powerful in this case.

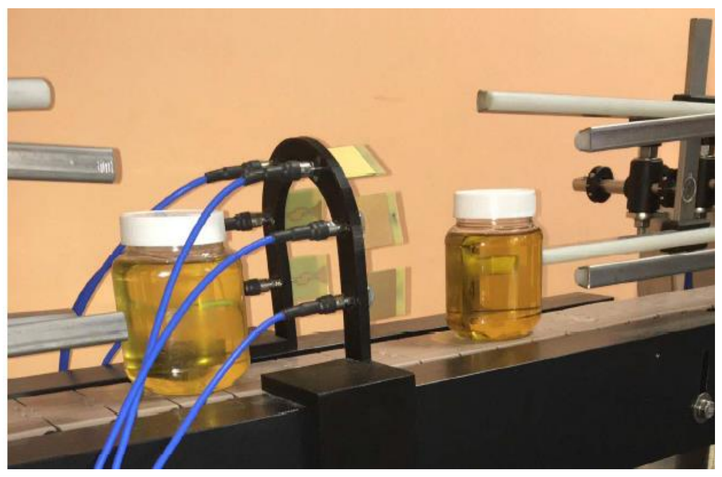


Data distribution on the 3 most significant eigenvectors. (a) Magnitude-only dataset. (b) Complex nature dataset.

Dataset nature	Magnitude only		Complex (real-imag)	
Classifier	MLP	Non-linear SVM	MLP	Non-Linear SVM
Dataset split	58% − 42% (720 samples for training and 520 samples for test)			
Optimization method	GWO	GWO	GWO	GWO
Average Performance	95.6%	99.2%	99.3%	99.8%

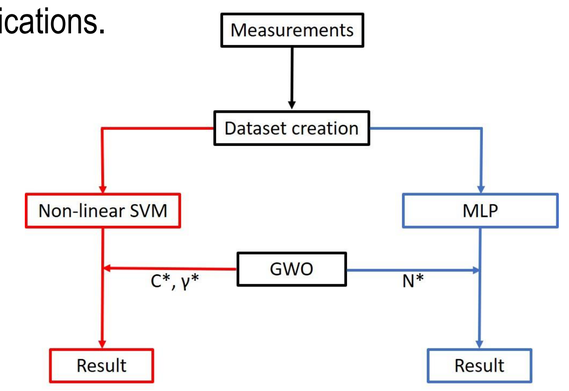
Novel contributions

- The novel detection principle here exploited, consists in the dielectric contrast between the background (the food medium) and the contaminant. The different permittivities, indeed, cause an alteration of the electromagnetic (EM) waves, that, if correctly acquired, could lead to the notification of a foreign body.
- This requires the development of a microwave sensing system that can operate in real-time at the speed of a fast conveyor belt that carries the packages in an industrial production line process.
- The acquired signals from the antennas operating at microwave frequencies are employed in combination with specific machine learning (ML) tools to binarily classify the food samples into contaminated or uncontaminated products.



Adopted methodologies

- A novel approach that starts from measurements setup and ended with a binary classification of food products into contaminated or uncontaminated. The work focused on combining MW sensing technology and ML tools like MLP and SVM in a complete workflow that can operate in real-time in a food production line.
- We investigated and applied some ML tools like SVM and MLP algorithms as they have been used in similar applications.



Future work

- Validating the performance of the system using different types of food products, so we can apply our methodology to new types of measurements and datasets.
- Investigating more optimization methods that may enhance the results we obtained.

List of attended classes

- 01QAAAA – ESoA. Diagnostic and Therapeutic Applications of Electromagnetics. Rome, (June 13-17, 2022, 3 credits).
- 02QAAAA – ESoA. Advanced Computational Electromagnetics. Turin, (September 19-23, 2022, 3 credits).

Submitted and published works

- Darwish, A.; Ricci, M.; Zidane, F.; Vasquez, J.; Casu, M.; Lanteri, J.; Migliaccio, C.; Vipiana, F., "*Physical Contamination Detection in Food Industry Using Microwave and Machine-Learning*", MDPI, 2022.