PÔSTER - RESUMO - SENSORES E BIOSSENSORES

PLANT-BASED BIOSENSORS FROM STOMATAL SPATIAL PATTERNS: A GRAPH-LLNA APPROACH

Victor Richard Cardoso (vrichard.cardoso@gmail.com)

Humberto Antunes De Almeida Filho (elfpedra@gmail.com)

João Vitor Bevilacqua De Souza Merenda (joao.merenda@usp.br)

Odemir Bruno (bruno@ifsc.usp.br)

Plant organs can act as biosensors by integrating environmental conditions into measurable morphological and physiological traits. In this work, we investigate the feasibility of using leaf phenotypic plasticity, more specifically, the spatial distribution pattern of stomata, as a sensing mechanism to infer the climatic conditions and/or air quality to which plants were exposed. Stomata are microscopic epidermal structures that regulate gas exchange and transpiration, and their density and spatial organization can change as adaptive responses to environmental stressors and resource availability.

Our proposed biosensing pipeline is based on converting stomatal spatial organization into a computational representation that can be automatically analyzed by pattern recognition methods. First, a leaf surface image is acquired and processed so that all stomata are detected and mapped, producing a "stomatal map" that preserves the spatial arrangement of stomata across the epidermis. Rather than reducing this information to simple summary statistics (e.g., average density), we encode the spatial distribution as a network (graph). In this representation, stomata are modeled as nodes and edges are created according to spatial neighborhood relations, enabling the use of tools from complex networks and graph-based learning.

To identify signatures associated with different exposure conditions, we employ LLNA (Life-Like Network Automata), a machine learning framework for pattern recognition on networks that combines complex network modeling with cellular automata-like dynamics. By evolving local rules over the stomata-derived graph, LLNA generates discriminative descriptors that capture mesoscopic and topological differences between stomatal patterns. This approach is particularly suitable for biological sensing scenarios because it can leverage relational structure and spatial organization, which often carry biologically meaningful information beyond scalar measures.

The results obtained in this assay indicate that stomatal distribution patterns exhibit measurable plasticity under different conditions, and that the proposed graph-based LLNA pipeline can capture these differences, supporting the potential of the method as a plant-inspired biosensor. Beyond its immediate application, the methodology suggests a general strategy for biosensing based on morphological pattern encoding: transforming biologically formed spatial microstructures into networks and applying graph-oriented learning to decode environmental exposure.

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Palavras-chave: biosensors; stomatal distribution; complex networks; machine learning; network automata.