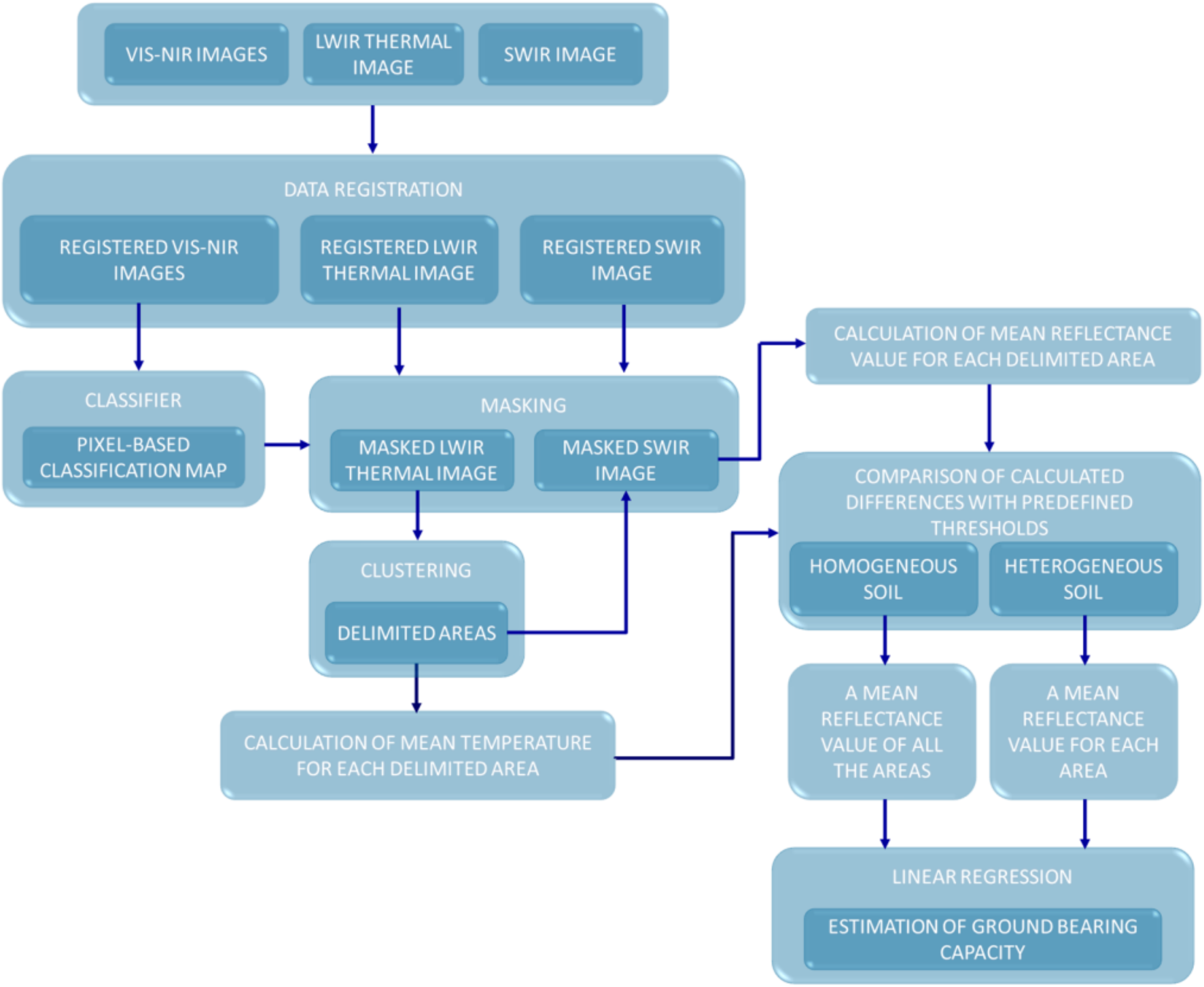
Estimation of the ground bearing capacity by means of VIS-NIR, SWIR and LWIR imagery

The indiscriminate use of agricultural and forestry machines cause compaction and rutting, producing severe soil damage. When soil is compacted and/or rutted, its porosity decreases, and consequently, the amount of oxygen that is required for a healthy function of plant roots. In order to contribute to the soil protection, a sensory system based on Visible-Near InfraRed (VIS-NIR), Short-Wave InfraRed (SWIR) and Long-Wave InfraRed (LWIR) imagery, and a sequential algorithm, have been proposed for estimating the ground bearing capacity, which can be defined as the ability of the soil to carry a certain weight without being damaged. The proposed solution can be utilized in natural scenarios, in real-time and in a non-destructive manner, and it can be very useful in decision making processes that tend to reduce ground damage during agricultural and forestry operations carried out with wheeled/tracked mobile robots, machines or vehicles.



The sequential algorithm for estimating the ground bearing capacity combines:

- A registration procedure. VIS-NIR, SWIR and LWIR images come from cameras that exhibit different field of view and different pixel array. To overcome this problem, an algorithm is adopted for registering the images acquired with the different cameras that compose the sensory rig, in such way that a direct correspondence between the pixels of the different images is obtained.
- A classifier that is applied to registered VIS-NIR images and trained to label the pixels of these images into three classes that are: soil, vegetation and others. The resulting pixel-based classification map is then utilised for generating a mask that will allows us to work only with those pixels that belong to the soil class in the next processing steps, and discard the rest of them.
- The masking of the registered SWIR and LWIR images by using the pixel-based

classification map obtained in the previous step.
A clustering that is applied to the soil pixels of the masked LWIR thermal image with the aim of partitioning soil pixels into several clusters. The idea is to delimit areas with different temperatures and consequently, areas that are candidates to present different water content. However, temperature values are disregarded for the direct estimation of the ground bearing capacity due to its high variability depending on several external factors.These clusters are then utilised for delimiting the areas where the mean temperatures and the mean reflectance values are calculated from the thermal and the normalised SWIR images, respectively. Next, the absolute differences from the mean values of the clustered areas are calculated and compared with certain predefined thresholds that will help us to determine if the soil sample has a homogeneous bearing capacity, or if on the contrary, the soil is heterogeneous. If soil is homogeneous a unique mean reflectance value is calculated from the soil pixels of the normalised SWIR image. If the soil is heterogeneous, a mean reflectance value is calculated for each area of the normalised SWIR image.
A linear regression that is utilised for modelling the relationship between the penetration resistance and the mean reflectance value of a normalised SWIR image.

Therefore, the sensory system and the proposed algorithm can be installed on-board a mobile robot or vehicle for estimating ground conditions before traversing the field, avoiding disturbances of the site and significantly reducing ground damages.

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