Development for Environmentally-Relevant Educational Scenarios with Arduino Kits

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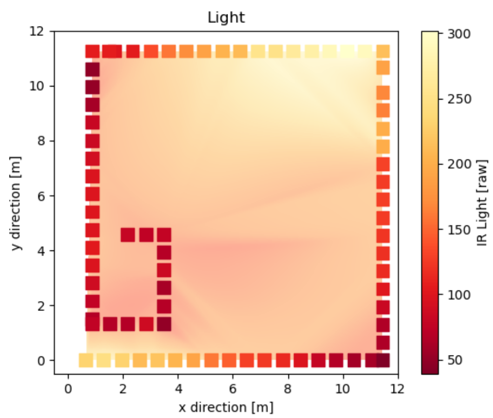
Embedded systems play a crucial role in environmental monitoring due to their efficiency, autonomy, cost-effectiveness, and adaptability. They facilitate precise and continuous data collection in challenging climate conditions while supporting remote accessibility and scalability. In this project, we aimed to design relevant scenarios that could help Environmental Sciences and Engineering students realize the potential of these systems. The one used in this project is an Arduino kit containing several measurement sensors (temperature, humidity, light, accelerometer, distance) and an XBee module for communication.

The idea developed to achieve this goal is to create an environmental conditions mapper. As it is adapted for classroom use, the main goal is to localize the Arduino board as a user walk around an indoor environment. The measurements are taken simultaneously and can be associated with the computed position, allowing maps to be created.

The first scenario we developed makes use of the accelerometer in the form of a step-counter. After calculating the step length of the user and the variance associated with the use of the step counter in an external script, we can estimate the position of the user by counting the number of steps taken in a direction. We also make use of the distance sensor in the kit to detect the presence of walls, to get another estimate of the position. We fuse these two sources of information with a Kalman filter, to get the optimal combination of the two positions. We make use of the buttons on the kit to indicate 90° turns so as to have a 2-dimensional mapper, and it is not possible to know the direction of travel with the minimum hardware at hand. In addition to this, we created instructions to help any student who would like to implement this mapper in a more guided and didactic manner.

This scenario aims to do the quite difficult and still researched task of indoor localization with minimal hardware. It does not aim to be perfect and has a few limitations. These include the lack of a ground-truth value of the absolute position, which makes it difficult to assess the actual precision of the mapper, or obstacles sticking out of the walls that can distort distance sensor measurements.



Example of resulting map

A second scenario is proposed, with the addition of a new sensor to the kit. This sensor is a 9DOF IMU sensor, that contains a gyroscope, magnetometer and accelerometer. This sensor adds the possibility of computing the 3D orientation of the Arduino board in space. This orientation could allow us to use the accelerometer values to get the position after integration. Unfortunately, this approach showed a significant drifting in the position mainly due to the noise and errors in the acceleration data. Even after trying various techniques (low-pass filters on acceleration to reduce the noise, high-pass filter on velocity to reduce the constant error), the computed position was never reflecting the true position of the sensor. Simplifying assumptions would be needed to achieve a more precise indoor localization with this specific hardware (for example putting the sensor on the foot of the user and use zero-velocity detection algorithms to reset the velocity and thus the error after each step).