Engineers Without Borders

Electronics Team: iSondlo Garden Sub-System External Parameters and Constraints

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This aims to document the external parameters and constraints affecting the growth of plants in the iSondlo Garden. The main vegetable in theis spinach (*Spinacia oleracea*).

Some good looking spinach[1]

Ready to eat full grown spinach[2]

The state of the environment that the spinach grows in must be controlled to produce the best possible quality vegetable. The electronics team aims to maintain the optimum conditions for growth using an Arduino-based system. The system uses four sensors to monitor the state of the environment, namely, temperature; humidity; soil moisture; and light sensors. To maintain suitable conditions, the system controls the flow and distribution of water to the plants. We also aim to monitor and control the environment together such that water is consumed in a sustainable manner.

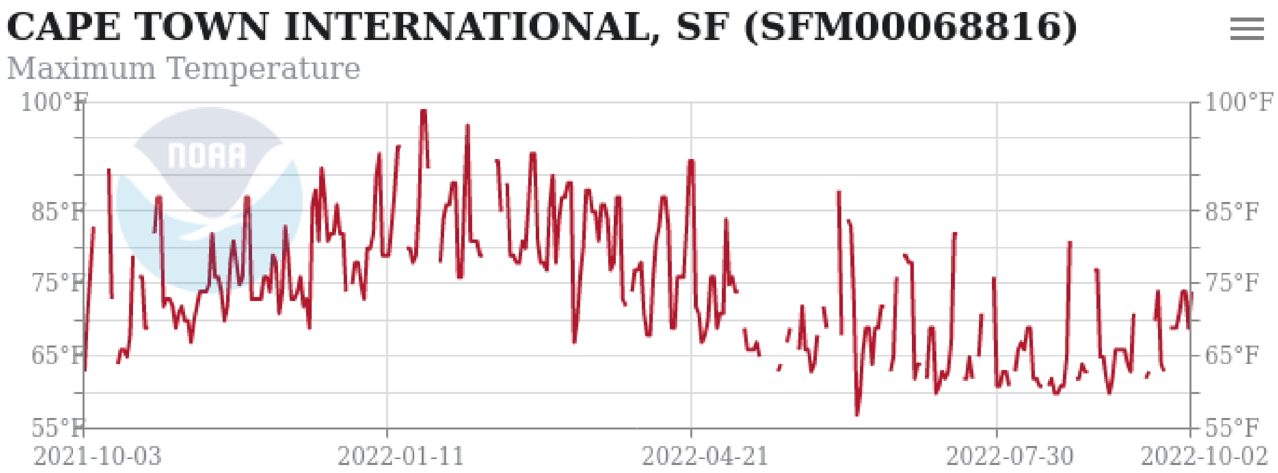
This paper does not include the variables associated with the operation of the network connection module and storage and manipulation of data in the SD card module.

Plant description

Spinach is a leafy vegetable which grows well in cool weather and in full sun to light shade. There are different types of spinach but each typically has smooth leaves with green leaves on a stem that grows vertically. Spinach produces yellowish green flowers in high temperatures before seeding. It grows to maturity in six to eight weeks with leaves reaching 10 cm to 17 cm at maturity. It is recommended to plant spinach seeds in cool soil temperatures between 7℃ to 15℃ and maintain the soil temperature between 16℃

and 24°C after germination. Temperatures above the recommended range affect the taste of the spinach, making it taste more bitter. The soil moisture can be maintained and the temperature kept cool by adding mulch to the soil. The highest recorded temperature in Cape Town, in 2022, was recorded in February at 32.28°C and the lowest recorded temperature was 8.33°C in June[3]. The average temperature in between October 2021 and October 2022 was 16.11°C.

Graph showing maximum temperature trends around Cape Town International Airport[4]



Spinach grows taller for days longer than 14 hours but if incident light is too bright and the temperature is too high, the plant will grow its floral stem prematurely. It requires constant soil moisture and humidity. The recommended humidity for the plants should be in the range of 90%-95%. In Cape Town, the relative humidity of the air ranges between 70% in November to 85%. Howevev, if the soil moisture and temperature needs are met, then humidity is typically not an issue.

Spinach requires to be watered frequently but without making the soil to soggy as the it will struggle to grow. Watering frequently becomes very important on days with high temperature to prohibit premature flowering. It is recommend to give spinach 2.54 cm to 3.81 cm of water per week[5]. Values in this range should be achieved as an average of watering periodically rather than deeply to avoid making the soil soggy.

Each sensor has an associated variable to monitor and the Arduino is given low-value triggers, high-triggers and baselines corresponding to the recommended threshold values for each variable. To obtain suitable measurements of soil moisture, the soil moisture sensor should be calibrated to give values between 300 and 700 for 2.54 cm to 3.81 cm of water. The automated irrigation system should be calibrated to dispense the correct amount of water each time by measure the amount of time that the solenoid valve should be open.

Constant Variables and Monitored Variables

Table 1 on summarises the variables that are going to be monitored and the low-value triggers and high-value triggers associated with the minimum and maximum values for growing good quality spinach.

Table 1: Showing the variables that will be programmed in the Arduino to ensure optimum plant growth

Sensor Model and function	Variables	Description	Initial Value
MAXIM DS18B20 Temperature Sensor	***uint8_t MIN_TEMP***	Constant minimum recorded temperature based on historical climate data [in °C]	8
	uint8_t MAX_TEMP	Constant maximum recorded temperature based on historical climate data [in °C]	32
	uint8_t MIN_SEED_TEMP	Constant minimum tolerable temperature before germination [in °C]	7
	uint8_t MAX_SEED_TEMP	Constant maximum tolerable temperature before germination [in °C]	14
	uint8_t MIN_SPIN_TEMP	Constant minimum tolerable temperature after germination [in °C]	16
	uint8_t MAX_SPIN_TEMP	Constant maximum tolerable temperature after germination [in °C]	24
	uint16_t hourlyTemp1	Determined from the digital 9 bit output value Stored hourly and reset hourly.	0
		Variable calculated from	

	uint8_t dailyMeanTemp	the hourly temperature. Store and reset daily.	0
	uint8_t weeklyMeanTemp	Variable calculated from daily average. Stored and reset weekly.	0
	uint8_t monthlyMeanTemp	Variable calculated from weekly average.	0
Ghitron HMZ-333A1 Humidity Sensor	***uint8_t MIN_Humidity***	Minimum relative humidity of the air that can be expected in Cape Town during the year [%]	40
	uint8_t MAX_Humidity	Maximum relative humidity of the air that can be expected in Cape Town during the year [%]	85
	uint8_t hourlyHumidity3	Relative humidity determined from the DC output of the sensor every 3 hours and is stored and cleared hourly.	0
	uint8_t dailyMeanHumidity	Computed from the hourlyHumidity. Stored and cleared after computing weekly average relative humidity.	0
	uint8_t MIN_MOISTURE	Minimum value associated with humid soil. Sensor has values in the range [300, 700] for humid soil.	310

KEYES KE2023 **Soil Moisture Sensor**	***uint8_t MAX_MOISTURE***	Minimum value associated with humid soil. Sensor has values in the range [300, 700] for humid soil.	650
	uint8_t hourlyMoisture1	Soil moisture recorded hourly. If this value is smaller than MIN_MOISTURE, the valve in the irrigation system is opened. Otherwise the valve remains closed.	0
	uint8_t dailyMeanMoisture	Average soil moisture computed daily. Used to keep track of daily water consumption for sustainable water usage.	0
	uint8_t weeklyMeanMoisture	Average soil moisture computed weekly. Used to ensure that water is used sustainably. Result is compared to growth of plants over a week.	0
	uint8_t monthlyMeanMoisture	Average soil moisture computed monthly. Used to ensure that water is used sustainably. Result is compared to the condition of the plant over a month.	0
	uint8_t MIN_LIGHT	Corresponds to the value obtained from the LDRs when the LDRs are completely shaded [%]	0

LDRs **Light Sensor**	***uint8_t MAX_LIGHT***	Corresponds to the value obtained from the LDRs when the LDRs are completely illuminated [%].	100
	uint8_t currentLight	The current value obtain from the LDRs.	0
	boolean lightOK	True if the value of the currentLight is greater than or equal to 50% otherwise the value is stored and a warning is transmitted.	false

The soil moisture sensor, humidity sensor and LDRs need to be calibrated to produced the desired values for computation. For example, more than one LDR can be used in a Wheatstone bridge configuration to achieve a linear relationship between the amount of incident light and the amplitude of the voltage signal received by the Arduino. The value of the output from the LDRs when they are completely occluded will correspond to a value of 0%. The values of the output that are higher than the value obtained when the LDRs are in sunlight on a sunny day correspond to 100%.

Variables related to the control of the system are included in the table below. These include the time-keeping capabilities which allow for recording values and operating the solenoid valve in the irrigation system. Some of the values have yet to be calibrated to ensure that resources are distributed in an effective and sustainable way.

Control Variables

Table 2: Showing the control variables used to maintain the good conditions for plant growth

Variable Name	Type	Description
startDate	**struct**	Value of the date recorded when the seeds are planted in the form DD:MM:YYYY where each variable is of type *uint8_t*.
endDate	**struct**	Value of the date recorded when the plants are harvested in the form DD:MM:YYYY where each variable is of type *uint8_t*.
currentDate	**struct**	Value of today's date in the form DD:MM:YYYY where each variable is of type *uint8_t*.
currentTime	***uint8_t***	Network time for measuring when a unit of time (hours, days, weeks and months) have elapsed.
HOUR	***uint8_t***	Network time (currentTime) plus 60 minutes.
DAY	***uint8_t***	Network time (currentTime) plus 24 hours.
WEEK	***uint8_t***	DAY*7.
MONTH	***uint8_t***	Network time (currentTime) plus 27, 28, 29 or 30 days.
valveStatus	***int***	Value showing the status of the solenoid valve. If the value is -1, then the relay switch to the solenoid valve is not connected. If it is 0, then the valve is connected but is not operational. If the status is 1, then the valve is operational.

valveOnTime	***uint8_t***	Computed from the value of the soil moisture and humidity to determine the length of time that the valve should be opened for. The larger the value of the soil moisture, the shorter the amount of time the valve should be opened. High relative humidity values (above 75%) reduce the value.