SCHOOL OF ENGINEERING

[MNGT413-202122]

[Management of Design – Case Study]

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Case Study:

A UK based company specialises in professional land-based weather stations. Recently, the company has decided to expand their market in the UK and produce a new compact personal weather station aimed at weather enthusiasts. The design team has adopted the six phases model of the Design Process presented in this module to develop the new weather station.

Clarification of the selection criteria:

Portability – the user should be able to use the product in a variety of environments and locations.
Costs – the product should be relatively low cost to appeal to the target customer, i.e. weather enthusiasts.
Integration with the internet – in relation to components of the product and interaction with the product, e.g. sensors, data analysis.
Sustainability – consider resources required during the use of the product and the end-of-life processing of all components.

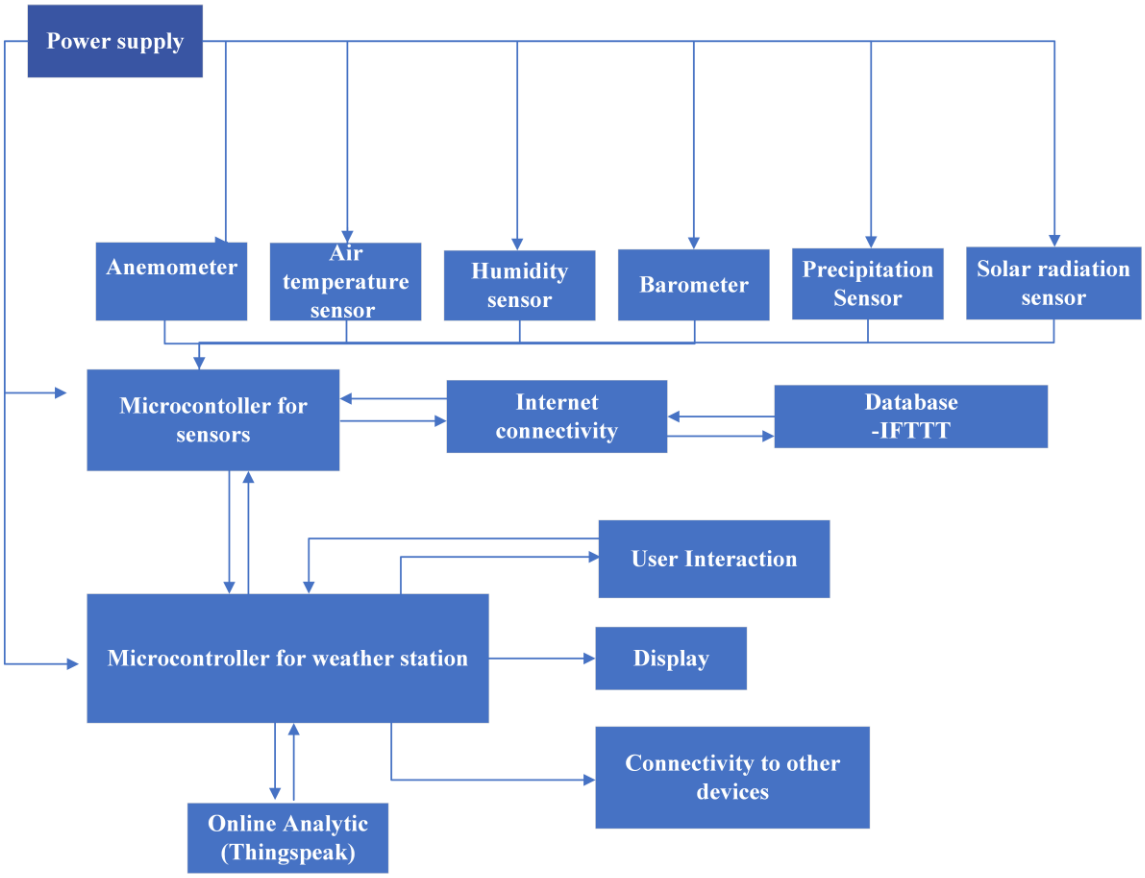
Contents

Compact Personal Weather Station: Conceptual design process

(a)Function Structures

Functions in conceptual Design for a compact personal weather station

- **Monitoring functions:** *Wind speed, Air temperature, Air pressure, Solar radiation, Precipitation, Humidity.*
- **Support functions:** *Power supply, Microcontrollers, Interaction, Internet connectivity*



(b) Solution Principles:

At least 3 solution principals for monitoring and support functions are given below:

GROUP	FUNCTION STRUCTURE	CODE	SOLUTION PRINCIPLES
Monitoring functions			

A	**Wind speed**	A1	Hot wire anemometers
		A2	Vane anemometer
		A3	Ultrasonic anemometer
		A4	Laser Doppler anemometers
B	**Air temperature**	B1	Thermistor
		B2	Thermocouples
		B3	Resistive temperature detectors (RTD)
C	**Humidity**	C1	thermal hygrometers
		C2	Capacitive hygrometers
		C3	Resistive hygrometers
D	**Air pressure**	D1	MEMS sensor (BME280 pressure, humidity, and temperature**)**
		D2	Mercury barometer
		D3	Aneroid barometer
E	**Precipitation**	E1	Tipping bucket gauge
		E2	Doppler radar sensor
		E3	Disdrometer
F	**Solar radiation**	F1	Photovoltaic pyranometer
		F2	Thermopile pyranometer
		F3	Quantum sensor
		F4	Pyrgeometer
Support functions			
G	**Power supply**	G1	Solar cell

		G2	Battery
		G3	Main power
H	**Micro controllers**	H1	Arduino
		H2	Teensy
		H3	ESP32
I	**Interaction**	I1	Touchscreen display
		I2	Buttons and switches
		I3	Voice controlled
J	**Internet connectivity**	J1	Wi-Fi
		J2	Ethernet cable
		J3	ISDN

(c) Combination of solution principles:

Ten representative combinations, which will allow to effectively demonstrate the application of approach are listed below:

Solution Variant	Combination of Solution Principles [A+B+C+D+E+F+G+H+I+J]
1.	A2+B1+C1+D1+E1+F2+G2+H1+I1+J1
2.	A1+B1+C1+D3+E1+F3+G3+H2+I3+J2
3.	A3+B3+C1+D1+E1+F2+G2+H1+I1+J1
4.	A1+B3+C1+D1+E1+F3+G3+H1+I1+J2
5.	A2+D1+E1+F2+G2+H3+I1+J1
6.	A1+D1+E1+F2+G2+H1+I1+J1
7.	A2+B2+C2+D2+E2+F3+G3+H2+I2+J2
8.	A4+B3+C3+D3+E1+F2+G3+H1+I1+J3
9.	A3+B3+C1+D1+E1+F3+G3+H2+I1+J1
10.	A2+B1+C1+D1+E1+F2+G2+H3+I1+J1

Anemometers used in solution variants are vane, hot wire and ultrasonic. All three are portable and compact. Hot wire and ultrasonic anemometers are more accurate and sensitive than vane, but they are harder to integrate as they need a specialized unit to calibrate the data.

To measure air temperature thermistor and RTD are used. Although thermistors are easy to integrate, low power consumption and much more sensitive than RTD they are fragile, and output is not as accurate as an RTD unit.

Among the three hygrometers thermal hygrometers are better as they provide more accurate results and unlike capacitive and resistive hygrometer's they don't need constant calibration and maintenance

Barometer's solutions include mercury, aneroid & MEMS barometers. Among which a MEMS units would be most preferable option as some of them are able to even measure humidity and air temperature. Accuracy might be little lower than dedicated device, but they are suitable for weather forecast.

Tipping bucket gauge is the most preferred to measure precipitation as they are simple to use, robust, compact and give accurate results.

For measuring Solar radiation both Thermopile pyranometer and Quantum sensor have similar accuracy, but Thermopile sensors are more portable.

For power supply having both main input and battery is good option. Having only main power input would significantly reduce the weight but having a battery backup would make it more portable.

Among the 3 microcontrollers suggested Arduino has the highest processing speed while other two are still suitable for weather station application. ESP32 comes with a built in Wi-Fi.

User interaction to change and use different features can be achieved by having a touch screen display or buttons to navigate. Voice operation is most convenient but not very reliable.

For the internet connection boards like Arduino and teensy come with a built-in ethernet cable port where as for WIFI and ISDN additional parts are needed.

(d) Solution Variants:

Initial evaluation of the individual combinations stated in **(c)** against the **three** essential selection criteria: **portability**, **costs** and **integration with the internet**.

Solution Variant (SV)	Portability	Cost	Integration with internet
1.	0	1	0
2.	0	0	0
3.	1	0	1
4.	0	1	1
5.	1	1	1
6.	1	1	1
7.	0	1	0
8.	0	0	0
9.	0	0	0

10.	1	1	1

0- Bad
1- Good

Highlighted rows are solution variants to be taken forward as the concept variants.

CV1=SV3	
Wind speed	Ultrasonic anemometer
Air temperature	Resistive temperature detectors (RTD)
Humidity	thermal hygrometers
Air pressure	MEMS sensor (BME280 pressure, humidity, and temperature**)**
Precipitation	Tipping bucket gauge
Solar radiation	Thermopile pyranometer
Power supply	Battery
Micro controllers	Arduino
Interaction	Touchscreen display
Internet connectivity	Wi-Fi

CV2=SV4	
Wind speed	Hot wire anemometers
Air temperature	Resistive temperature detectors (RTD)
Humidity	thermal hygrometers
Air pressure	MEMS sensor (BME280 pressure, humidity, and temperature**)**
Precipitation	Tipping bucket gauge
Solar radiation	Quantum sensor
Power supply	Main power
Micro controllers	Arduino
Interaction	Touchscreen display
Internet connectivity	Ethernet cable

CV3=SV5	
Wind speed	Vane anemometer
Air temperature	MEMS sensor (BME280 pressure, humidity, and temperature**)**
Humidity	MEMS sensor (BME280 pressure, humidity, and temperature**)**

Air pressure	MEMS sensor (BME280 pressure, humidity, and temperature**)**
Precipitation	Tipping bucket gauge
Solar radiation	Thermopile pyranometer
Power supply	Battery
Micro controllers	ESP32
Interaction	Touchscreen display
Internet connectivity	Wi-Fi

CV4=SV10	
Wind speed	Vane anemometer
Air temperature	Thermistor
Humidity	thermal hygrometers
Air pressure	MEMS sensor (BME280 pressure, humidity, and temperature**)**
Precipitation	Tipping bucket gauge
Solar radiation	Thermopile pyranometer
Power supply	Battery
Micro controllers	ESP32
Interaction	Touchscreen display
Internet connectivity	Wi-Fi

The four solution variants SV3, SV4, SV5, SV10 are sort listed taking 3 major criteria into consideration portability, cost & internet integration. Although few of selected solution variants satisfy all three criteria there are few solution variants that might be bad in one of the criteria, but they make up by being more accurate or responsive. In all the selected solution some might be much more portable than others while some might be more cost effective. So, it is necessary that they are compared further to find out the combination that more balanced in nature.

SV3 despite being more expensive it is a combination of highly accurate and robust sensors and processor. It has Wi-Fi connectivity and battery for power supply making it an attractive option despite the cost.

SV4 Although it needs to be plugged in and an ethernet connection to operate, compromising on portability but as trade off it is light weight, robust and comes with sensors that have high accuracy and sensitivity. The absence of battery reduces the cost making it an affordable option.

SV5 This cheap, portable and has good internet connectivity with the need of an extra unit. The absence of specialised sensor for air temp and humidity reduces the accuracy but the data is still useful for a personal weather station. The absence of additional sensors and using ESP32 chip reduces the power requirement hence smaller battery making it lighter.

SV10 This is like SV5 but has additional sensors for humidity and temperature increasing the accuracy but there might be increase in cost and decrease in portability.

(e) Concept variants, Evaluation:

Detailed evaluation of the concept variants selected in **(d)** against the **three** essential criteria listed above and an additional criterion of **sustainability** & **accuracy**.

Criteria	Weighting (Wt.)	CV1		CV2		CV3		CV4	
		Value(V)	Wt.*V	Value(V)	Wt.*V	Value(V)	Wt.*V	Value(V)	Wt.*V
Portability	0.200	3	0.600	1	0.200	4	0.800	3	0.600
Cost	0.230	2	0.230	3	0.690	4	0.920	3	0.690
Internet integration	0.180	4	0.720	2	0.360	3	0.540	3	0.540
Sustainability	0.150	2	0.300	4	0.600	3	0.450	2	0.300
Accuracy	0.240	4	0.960	3	0.720	2	0.480	3	0.720
Total-	1.00		2.81		2.57		3.19		2.85

Scheme	Value
Bad	0
Tolerable	1
Acceptable	2
Good	3
Excellent	4

According to the above evaluation, the primary layout CV3 is chosen for further coming design stage.

Although there are many possible criteria that can be taken into consideration for development of a personal weather station but the major factors like portability, cost, internet integration and accuracy are taken into consideration for this product.

The selection for final primary layout is done by weighting the importance of each criteria and comparing them with others. The weightage for each criteria is given based from what average customers find important when buying the product.

Accuracy is the most important criteria for a personal weather station but sometimes customer is willing to compromise for products that cost less. So, the second important criteria are Cost but it's almost equally important as accuracy as the difference in accuracy is acceptable. The third most important criteria would be portability which is affected largely by factors like size, weight, power source and connectivity hence the values are assigned taking these factors into consideration. Internet connectivity could be more important for some people than portability but since all concept variants use almost similar means of connectivity, they are given less importance while comparing. If an Arduino processor can connect through Wi-Fi, it would still be able to connect to an ethernet cable making it superior. The final factor is sustainability although it should be one of the major factors ironically the number of weather station enthusiast who are considerate about sustainability are few. Hence it has been given the least weightage, the value is given based on energy consumption and battery size needed to operate them.

The result of this comparison suggests that CV3 despite having an acceptable accuracy is comparable to other concepts and stands out in Cost, Portability and Sustainability making it most suitable for customers, hence it chosen for upcoming design stages.

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