METU ME462 Mechatronic Design, Spring 2020

Design Evaluation: Design and manufacture of a wheeled robot controlled by the movement of a fish swimming inside an aquarium

Say My Name
Sercan Aslan / 1909902
Ali Levent Çınar / 2234532
Yusuf Can Coşkun / 1939420

March 2, 2020

Design alternatives has been explored for each function of a wheeled robot controlled by the movement of a fish swimming inside an aquarium (Robofish). The functional decomposition schematic of Robofish is as shown in Figure 1. The generated concepts for each function and their respective evaluation criteria has been summarized in Table 1 and 2. Note that the functions, concepts and evaluation criteria will be referred by their function ID (FID), concept ID (CID) and evaluation ID (EID), respectively, in the remainder of this document. The CID of the highest scoring concepts will be presented in bold throughout the document. Datum concepts will be denoted with a star. The evaluation criteria are weighted using the analytic hierarchy process (AHP) in Tables 3-15. The generated concepts are systematically evaluated in Tables 16-28 using weighted decision-matrix (Pugh) method.

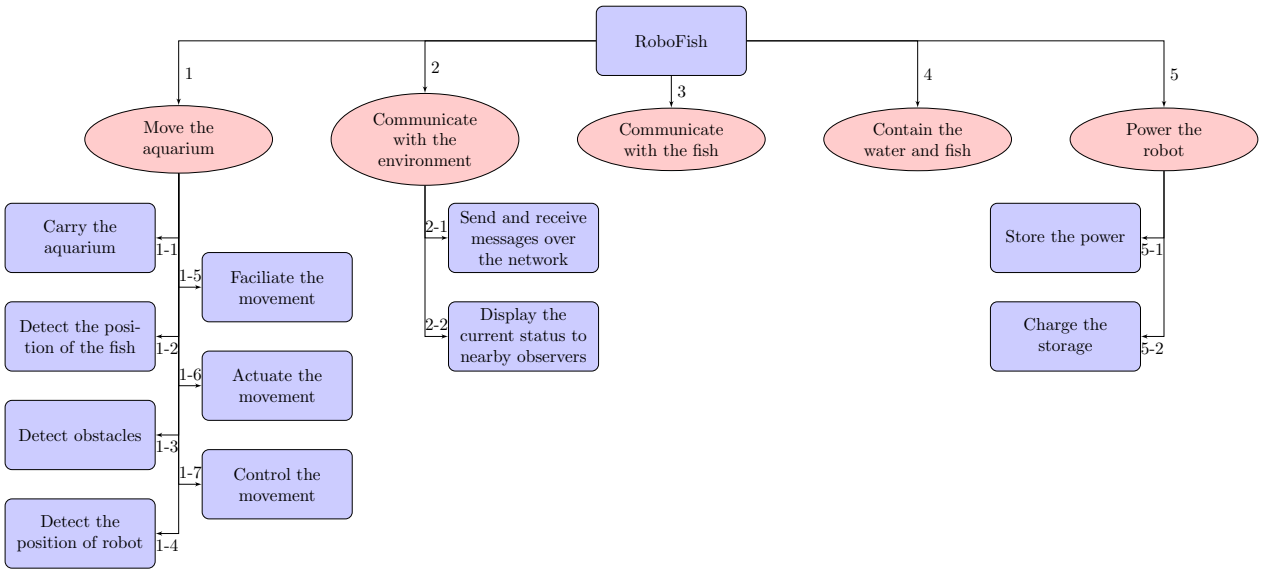

Figure 1: The functional decomposition.

Table 1: Generated concepts for the functions of Robofish

FID	Function Name	CID	Concept
1-1	Carry the aquarium	1-1C1	Glued platform
		1-1C2	Positive contact due to gravity
		1-1C3	Assembled to a platform with holes
		1-1C4	Components directly assembled
		1-1C5	Components directly assembled, segmented aquarium
1-2	Detect the position of fish	**1-2C1**	Webcam & Raspberry Pi
		1-2C2	ESP32-CAM
		1-2C3	Raspberry Pi Camera
1-3	Detect the obstacles	1-3C1	Ultrasonic sensors
		1-3C2	Wide lens camera on the robot
		1-3C3	Overhead camera (not attached to the robot)
1-4	Detect the position of robot	1-4C1	Overhead camera (not attached to the robot)
		1-4C2	Wide lens camera on the robot
		1-4C3	No camera (using available sensor data & encoder)
1-5	Facilitate the movement	**1-5C1**	3D printed mechanum wheels
		1-5C2	Machined mechanum wheels
		1-5C3	Differential drive
		1-5C4	Tracks
		1-5C5	Steered wheels
1-6	Actuate the movement	**1-6C1**	Brushless DC motor
		1-6C2	Brushed DC motor
		1-6C3	Stepper motor
1-7	Control the movement	**1-7C1**	Raspberry Pi
		1-7C2	Dedicated PC (connected via cable or network module)
		1-7C3	Arduino microprocessor
2-1	Send & receive network messages	**2-1C1**	Raspberry Pi
		2-1C2	Network module
		2-1C3	Arduino Wi-Fi module
2-2	Display the current status	**2-2C1**	LED indicator lights
		2-2C2	Speakers
		2-2C3	Monitor
3-1	Communicate with the fish	**3-1C1**	LED lighting
		3-1C2	Monitor (attached to the robot)
4-1	Contain the water & fish	**4-1C1**	Plastic aquarium
		4-1C2	Spherical glass aquarium
		4-1C3	Prismatic glass aquarium
5-1	Store the power	5-1C1	Ni-Cad battery
		5-1C2	Li-Po battery
		5-1C3	Li-Ion battery
		5-1C4	Dry accumulator
5-2	Charge the storage	**5-2C1**	Dangling magnet attached to the room
		5-2C2	Dangling magnet attached to the robot
		5-2C3	Mechanical connection
		5-2C4	Inductive charging

Table 2: Concept evaluation criteria for the functions of Robofish

FID	Function Name	EID	Evaluation Criterion
1-1	Carry the aquarium	1-1E1	Cost
		1-1E2	Removability (important for cleaning, removing water)
		1-1E3	Durability
		1-1E4	Aesthetics
		1-1E5	Manufacturability
1-2	Detect the position of the fish	1-2E1	Resolution
		1-2E2	Response time
		1-2E3	Cost
		1-2E4	Mountability
		1-2E5	Upgradability
1-3	Detect the obstacles	1-3E1	Precision
		1-3E2	Cost
		1-3E3	Response time
		1-3E4	Manufacturability
1-4	Detect the position of the robot	1-4E1	Cost
		1-4E2	Response time
		1-4E3	Precision
		1-4E4	Manufacturability
1-5	Facilitate the movement	1-5E1	Smoothness
		1-5E2	Range of motion
		1-5E3	Cost
		1-5E4	Durability (includes weight carrying capacity)
		1-5E5	Manufacturability
1-6	Actuate the movement	1-6E1	Noise
		1-6E2	Precision
		1-6E3	Durability
		1-6E4	Cost
		1-6E5	Ease of control (in order to ensure smooth motion)
1-7	Control the movement	1-7E1	Cost
		1-7E2	Performance
		1-7E3	Upgradability
		1-7E4	Continuity (resistance against power loss)
2-1	Send & receive network messages	2-1E1	Cost
		2-1E2	Performance
		2-1E3	Upgradability
2-2	Display the current status	2-2E1	Cost
		2-2E2	Manufacturability
		2-2E3	Aesthetics
		2-2E4	Range of messages (ability to convey different messages)
		2-2E5	Power consumption
3-1	Communicate with the fish	3-1E1	Cost
		3-1E2	Manufacturability
		3-1E3	Range of messages (ability to convey different messages)
		3-1E4	Power consumption
4-1	Contain the water & fish	4-1E1	Cost
		4-1E2	Mountability
		4-1E3	Weight
		4-1E4	Visibility (by the camera, if one exists)
		4-1E5	Aesthetics
5-1	Store the power	5-1E1	Cost
		5-1E2	Durability (life of the battery)
		5-1E3	Capacity per weight
5-2	Charge the storage	5-2E1	Cost
		5-2E2	Manufacturability
		5-2E3	Charging time (better if less)
		5-2E4	Durability

Table 3: AHP for 1-1: Carry the aquarium

	1-1E1	1-1E2	1-1E3	1-1E4	1-1E5	Weight (%)
1-1E1	1	1/5	1/7	1/3	5	12.4
1-1E2		1	3	7	5	43.3
1-1E3			1	7	1	24.5
1-1E4				1	1/5	7.08
1-1E5					1	12.7

Table 4: AHP for 1-2: Detect the position of fish

	1-2E1	1-2E2	1-2E3	1-2E4	1-2E5	Weight (%)
1-2E1	1	1	7	3	3	34.5
1-2E2		1	5	3	5	35.6
1-2E3			1	1/3	1/3	4.94
1-2E4				1	3	15.4
1-2E5					1	9.49

Table 5: AHP for 1-3: Detect the obstacles

	1-3E1	1-3E2	1-3E3	1-3E4	Weight (%)
1-3E1	1	5	1	3	37.2
1-3E2		1	1/5	1/3	6.74
1-3E3			1	5	42.6
1-3E4				1	13.4

Table 6: AHP for 1-4: Detect the position of the robot

	1-4E1	1-4E2	1-4E3	1-4E4	Weight (%)
1-4E1	1	1/5	1/5	1/3	6.87
1-4E2		1	1	3	38.9
1-4E3			1	3	38.9
1-4E4				1	15.3

Table 7: AHP for 1-5: Facilitate the movement

	1-5E1	1-5E2	1-5E3	1-5E4	1-5E5	Weight (%)
1-5E1	1	3	7	5	3	45.8
1-5E2		1	5	3	3	24.7
1-5E3			1	1/3	1/3	4.63
1-5E4				1	3	14.4
1-5E5					1	10.5

Table 8: AHP for 1-6: Actuate the movement

	1-6E1	1-6E2	1-6E3	1-6E4	1-6E5	Weight (%)
1-6E1	1	1/5	1/3	3	1/5	9.76
1-6E2		1	1	5	3	34.1
1-6E3			1	5	3	31.3
1-6E4				1	3	10.6
1-6E5					1	14.2

Table 9: AHP for 1-7: Control the movement

	1-7E1	1-7E2	1-7E3	1-7E4	Weight (%)
1-7E1	1	1/5	1/3	1/5	6.70
1-7E2		1	3	3	49.1
1-7E3			1	1/3	15.1
1-7E4				1	29.1

Table 10: AHP for 2-1: Send & receive network messages

	2-1E1	2-1E2	2-1E3	Weight (%)
2-1E1	1	1/5	1/5	8.97
2-1E2		1	3	60.7
2-1E3			1	30.3

Table 11: AHP for 2-2: Display the current status

	2-2E1	2-2E2	2-2E3	2-2E4	2-2E5	Weight (%)
2-2E1	1	1/3	1/3	1/3	1/5	5.91
2-2E2		1	1/5	1/3	1/3	10.5
2-2E3			1	1/3	1/3	19.1
2-2E4				1	1/3	23.9
2-2E5					1	40.6

Table 12: AHP for 3-1: Communicate with the fish

	3-1E1	3-1E2	3-1E3	3-1E4	Weight (%)
3-1E1	1	1/3	1/3	1/5	7.68
3-1E2		1	1/3	1/3	15.9
3-1E3			1	1/3	26.3
3-1E4				1	50.1

Table 13: AHP for 4.1: Contain the water & fish

	4-1E1	4-1E2	4-1E3	4-1E4	4-1E5	Weight (%)
4-1E1	1	1/5	1/3	1/3	1/3	6.00
4-1E2		1	3	3	3	41.4
4-1E3			1	3	3	24.7
4-1E4				1	3	16.8
4-1E5					1	11.2

Table 14: AHP for 5.1: Store the power

	5-1E1	5-1E2	5-1E3	Weight (%)
5-1E1	1	1/3	1/3	14.0
5-1E2		1	3	57.4
5-1E3			1	28.6

Table 15: AHP for 5.2: Charge the storage

	5-2E1	5-2E2	5-2E3	5-2E4	Weight (%)
5-2E1	1	1/5	1/3	1/3	7.65
5-2E2		1	5	3	54.3
5-2E3			1	1/3	13.6
5-2E4				1	24.5

Table 16: Decision-matrix for 1-1: Carry the aquarium

	(%)	1-1C1	**1-1C2**	1-1C3*	1-1C4	1-1C5
1-1E1	12.4	1	1	D	0	-1
1-1E2	43.3	-1	1	D	-1	-1
1-1E3	24.5	1	1	D	-1	-1
1-1E4	7.08	-1	1	D	-1	1
1-1E5	12.7	1	-1	D	-1	-1
	Total	-0.00689	**0.746**	0	-0.876	-0.858

Table 17: Decision-matrix for 1-2: Detect the position of fish

	(%)	**1-2C1***	1-2C2	1-2C3
1-2E1	34.5	D	-1	-1
1-2E2	35.6	D	-1	1
1-2E3	4.94	D	1	1
1-2E4	15.4	D	-1	-1
1-2E5	9.49	D	-1	0
	Total	**0**	-0.901	-0.0936

Table 18: Decision-matrix for 1-3: Detect the obstacles

	(%)	**1-3C1***	1-3C2	1-3C3
1-3E1	37.2	D	-1	-1
1-3E2	6.74	D	-1	-1
1-3E3	42.6	D	-1	-1
1-3E4	13.4	D	0	-1
	Total	**0**	-0.866	-1.00

Table 19: Decision-matrix for 1-4: Detect the position of the robot

	(%)	1-4C1*	**1-4C2**	1-4C3
1-4E1	6.87	D	-1	1
1-4E2	38.9	D	1	1
1-4E3	38.9	D	1	-1
1-4E4	15.3	D	1	1
	Total	0	**0.863**	0.222

Table 20: Decision-matrix for 1-5: Facilitate the movement

	(%)	**1-5C1**	1-5C2	1-5C3*	1-5C4	1-5C5
1-5E1	45.8	1	1	D	0	0
1-5E2	24.7	1	1	D	0	-1
1-5E3	4.63	0	-1	D	-1	-1
1-5E4	14.4	-1	0	D	1	-1
1-5E5	10.5	1	-1	D	-1	-1
	Total	**0.666**	0.554	0	-0.00708	-0.542

Table 21: Decision-matrix for 1-6: Actuate the movement

	(%)	**1-6C1**	1-6C2*	1-6C3
1-6E1	9.76	1	D	0
1-6E2	34.1	0	D	1
1-6E3	31.3	1	D	-1
1-6E4	10.6	-1	D	-1
1-6E5	14.2	-1	D	1
	Total	**0.163**	0	0.0636

Table 22: Decision-matrix for 1-7: Control the movement

	(%)	**1-7C1**	1-7C2	1-7C3*
1-7E1	6.70	-1	-1	D
1-7E2	49.1	1	1	D
1-7E3	15.1	1	1	D
1-7E4	29.1	0	-1	D
	Total	**0.575**	0.283	0

Table 23: Decision-matrix for 2-1: Send & receive network messages

	(%)	**2-1C1**	2-1C2*	2-1C3
2-1E1	8.97	-1	D	-1
2-1E2	60.7	1	D	0
2-1E3	30.3	1	D	0
	Total	**0.821**	0	-0.0897

Table 24: Decision-matrix for 2-2: Display the current status

	(%)	**2-2C1***	2-2C2	2-2C3
2-2E1	5.91	D	-1	-1
2-2E2	10.5	D	-1	-1
2-2E3	19.1	D	0	1
2-2E4	23.9	D	1	1
2-2E5	40.6	D	-1	-1
	Total	**0**	-0.332	-0.140

Table 25: Decision-matrix for 3-1: Communicate with the fish

	(%)	**3-1C1***	3-1C2
3-1E1	7.68	D	-1
3-1E2	15.9	D	-1
3-1E3	26.3	D	1
3-1E4	50.1	D	-1
	Total	**0**	-0.474

Table 26: Decision-matrix for 4-1: Contain the water & fish

	(%)	**4-1C1**	4-1C2*	4-1C3
4-1E1	6.00	1	D	-1
4-1E2	41.4	1	D	1
4-1E3	24.7	1	D	0
4-1E4	16.8	1	D	1
4-1E5	11.2	-1	D	-1
	Total	**0.777**	0	0.410

Table 27: Decision-matrix for 5-1: Store the power

	(%)	5-1C1	5-1C2	5-1C3*	**5-1C4**
5-1E1	14.0	1	-1	D	1
5-1E2	57.4	-1	1	D	1
5-1E3	28.6	-1	-1	D	-1
	Total	-0.720	0.147	0	**0.427**

Table 28: Decision-matrix for 5-2: Charge the storage

	(%)	**5-2C1**	**5-2C2**	5-2C3*	5-2C4
5-2E1	7.65	1	1	D	-1
5-2E2	54.3	1	1	D	-1
5-2E3	13.6	0	0	D	-1
5-2E4	24.5	1	1	D	1
	Total	**0.864**	**0.864**	0	-0.511