Conservation of water during shower with the application of sensors

Texas A&M University – Corpus Christi

Honors Program

Abstract

The purpose of this Project of Excellence is to apply a motion sensor to a showering assembly to conserve water. This was done by mimicking the functions of a touchless faucet to design an assembly that was applied to a stand-up shower. Thirty-six trials were done to show that water conservation is attainable through the application of sensors to a showerhead.

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Introduction

This research will give an extensive observation at the immense amounts of water consumed during a shower[1] routine. The focus of this research will be a shower routine versus a bath routine due to a shower usually using less water. The focus of using a shower head will be private use and not public use. The process of a combat[2] shower is loosely adopted in this application.

1.1. Background

On August 25, 2017, Hurricane Harvey made landfall in Texas as a Category 4 hurricane. It went on to impact several coastal states causing $125 million dollars in damage [1]. An estimated 13 million people were affected, nearly 135,000 homes damaged or destroyed and nearly a million cars were flooded [1]. President Donald J. Trump declared that a major disaster existed in the State of Texas and ordered Federal Aid to supplement state and local recovery efforts beginning on August 23, 2017 [2]. On August 23, 2017, County Judge C.H. “Burt” Mills Jr. issued a mandatory Evacuation Order and Disaster Proclamation for Aransas County due to impending Hurricane Harvey which was a direct hit to the community on August 25, 2017 [3]. County Judge C.H. “Burt” Mills Jr. issued a Hurricane Harvey Disaster Declaration Proclamation following Hurricane Harvey and has since continued to be renewed up until March 27, 2019. On March 15, 2019, Governor of the State of Texas, Gregg Abbott issued a proclamation stating that a state of disaster continues to exist in Texas as a result of catastrophic damage caused by Hurricane Harvey [4].

[1] Shower: When a person bathes under a spray of water from a showerhead at a certain pressure.

[2] combat shower: a method of showering that lasts less than two minutes with an initial thirty seconds to get wet, followed by shutting off the water, lathering and then rinsing for a minute. Originated of naval ships to conserve the supplies of fresh water.

Following the landfall of Hurricane Harvey, 220,000 AEP Texas customers were without power at the peak of outages on August 26th, 2017 [5] Rockport and Port Aransas, Texas were hit the hardest by the storm therefore restoration time was longer. On August 27th, 2017, AEP Texas had estimated to have 95% of the power restored for customers within the city of Corpus Christi and Sinton by August 30th [6]. The cities of Victoria, Beeville, El Campo and Kenedy were expected to have 95% of their power restored by Sept. 2nd [7].

Table 1. *The AEP Texas customers without power on Aug. 26th separated into area/cities*

Areas without Power	# of Customers
Aransas Pass – Rockport Area	47,000
Corpus Christi	76,000
Victoria	29,000
Port Lavaca	14,300
El Campo	9,300
Sinton	6,000
Beeville	5,000

Table 2. *AEP Texas customers remaining without power on Sept. 8th separated into area/cities*

Areas without Power	# of Customers
Aransas Pass – Rockport Area	15,000
Victoria Area	900
Port Lavaca – Refugio Area	645

AEP Texas estimated to have at least 3,100 utilities poles and 500 transmission structures damaged by Hurricane Harvey [7]. On Sept. 8th, 2017, approximately 203,400 of the 220,000 customers left without power had had their electric service restored with the outages below remaining in certain areas [8].

The Federal Emergency Management Agency (FEMA) reported that the Hurricane Harvey incident period was August 23rd-September 15th, 2019. A total of 379,649 individual assistance applications were received by FEMA. The total individual and household program[3] (IHP) dollars approved was $1,654,136,272.31. The total public assistance grants[4] dollars obligated was $1,399,248,179.11. The counties designated to receive individual assistance were:

Aransas, Austin, Bastrop, Bee, Brazoria, Caldwell, Calhoun, Chambers, Colorado, DeWitt, Fayette, Fort Bend, Galveston, Goliad, Gonzales, Grimes, Hardin, Harris, Jackson, Jasper, Jefferson, Karnes, Kleberg, Lavaca, Lee, Liberty, Matagorda, Montgomery, Newton, Nueces, Orange, Polk, Refugio, Sabine, San Jacinto, San Patricio, Tyler, Victoria, Walker, Waller, Wharton [9]

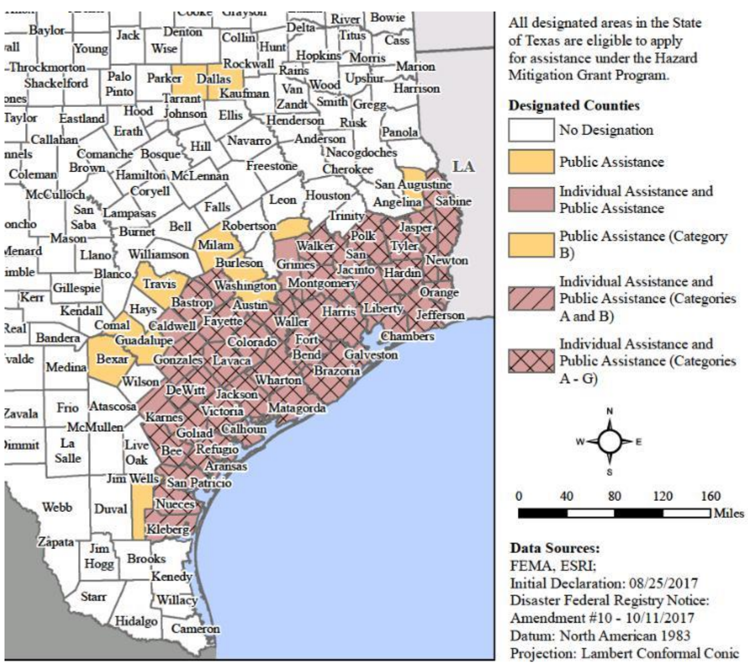

Figure 1. *A map of FEMA's disaster declaration as of October 11th, 2017 (DR-4332)*

[3] Individual and Household program: A FEMA funded program that can provide financial help and direct services after a disaster. The program provides money for necessary housing-related expenses and serious needs caused by the disaster.
[4] Assistance (FEMA) provides from federal funding under the Public Assistance (PA) Grant Program after a presidentially declared disaster for: states, tribal nations, local governments and private nonprofit organizations.

1.2 Motivation

My home is in Aransas County, between Aransas Pass and Rockport. On August 24th, 2017, my family and I evacuated to San Antonio at 4pm in the afternoon. I remember the news reported that there had been an announcement for those who had not evacuated to write on their forearm with permanent marker their First and Last Name, Date of Birth and Social Security number. Another the news reported looting happening in businesses and homes. It was all a dreadful experience. We returned on Sunday, August 27th to an isolated town with cattle and electricity poles obstructing roads. find dispersed farming grass bales from surrounding farms covering our yard (Fig.2). The mulch was a foot deep and contained cattle waste, snakes, eels and crawfish. In the yard, there was also two deceased cows. The days following, I detected foul odors I had never perceived before from the unknown sources.

Figure 2. *A view of the cattle able covering my front yard. Photo Credit:*

The fact that our home was still stand was deceiving (Fig.3). It was until we went inside that we saw the actual damage. The ceilings of my mother's room, sister's room, both bathrooms and porch had collapsed. Our garage had exploded in our backyard (Fig.4). It would be several weeks before public utilities would be restored in our area because we live outside the city limits of both Rockport and Aransas Pass.

Figure 3. *My home still standing Post-Hurricane Harvey.*

Figure 4. *My backyard where the garage used to be.*

The rural[5] area we live in has waterwell with a water pump (Fig.5) to produce water for daily use. Figure 1-5 shows a picture of the actual waterpump at my house. Our waterwell and waterpump work with electricity so during the power outage following Hurricane Harvey, there was no water. During this time, diaster relief supplied us with 5-gallon buckets to transport water. At one point we were transporting ten 5-gallon buckets to wash dishes and take showers. It was during this time that I realized I was able to shower with less than 10 gallons (two 5-gallon buckets). This realization was shocking! This is why I chose to do my Project of Excellence on research in the conservation of water.

Figure 5. *The water pump that brings water up from the ground*

[5] Rural area in this context is countryside that is a geographic area that is located outside towns and cities.

1.3 Applications

Motion sensor are very common on the Texas A&M University – Corpus Christi restrooms and around the world to help reduce the spread of bacteria. According to the Center for Disease Control and Prevention [12], proper handwashing is the single most effective means of preventing the spread of germs that can result in everything from the common cold and diarrhea to more serious and potentially life-threatening diseases. Manufacturers, such as Sloan[6], promote their products are water efficient and contribute to a higher level of handwashing hygiene through motion sensors [13].

2. Research

Theoretical research for this Project of Excellence began January 2018. During this time, patents and licensed products were investigated to establish a foundation for the application of IR motion sensors to faucets, commodes and shower heads. Multiple products for faucets and commodes exist that use IR motion sensors but very few for shower heads were found.

2.1 Sensing Technologies

Many kinds of sensing technologies exist such as infrared, microwave, vibration and ultrasonic. For the design of this research, infrared (IR) and capacitance (C) were initially compared. Infrared sensing operates when a user’s hands reflect an invisible light beam, alerting the faucet to begin the flow of water. Infrared sensors have been applied to not just restroom products but also doorways at commercial stores and outdoor products such as fences and security lights. Capacitance (C) sensing utilizes the human body’s own natural conductivity. When the faucet senses a hand, it starts the flow of water. There

[6] Sloan is a manufacturer of commercial bathroom products such as flushometers, fixtures, sinks and faucets

is no sensor window and critical components are protected in a watertight, below-deck box. In some instances, the proper functioning of capacitance technology can be inhibited by metal fixtures or the proximity of large metal objects [15]. Therefore, capacitance was not an ideal choice for shower applications. The sensing technology chosen for this project is infrared (IR). The IR motion sensors for commodes were also considered but later disregarded for having a range of 20 to 36 inches which was too large for this application.

2.2 Patents

U.S. Pat. No. 5,829,072 describes the general use of an IR motion sensor near the faucet handles of a shower to automatically start and stop the water flow based on presence of a person in the shower [18]. US. Pat. No. 4,998,673 described a system for controlling the flow of water from a showerhead by placing a sensor directly within the showerhead [19]. Limitations for these patents is the sensor’s permanent placement in the shower setting. Sensors are sensitive to the distance between itself and the showering person. Figure 7 shows a U.S. Pub. No.: US 2009/0293190 A1 is an application publication for a Showerhead Presence Detection system that combines infrared sensors with a mechanical height adjustment of the showerhead [17]. This system eliminates the limitation of the sensor’s permanent placement but adds mechanical work of adjusting the showerhead height adjuster to the showering person’s height. The design for this project will differ from patents described by adding a mount for the sensor which will allow easy adjustment.

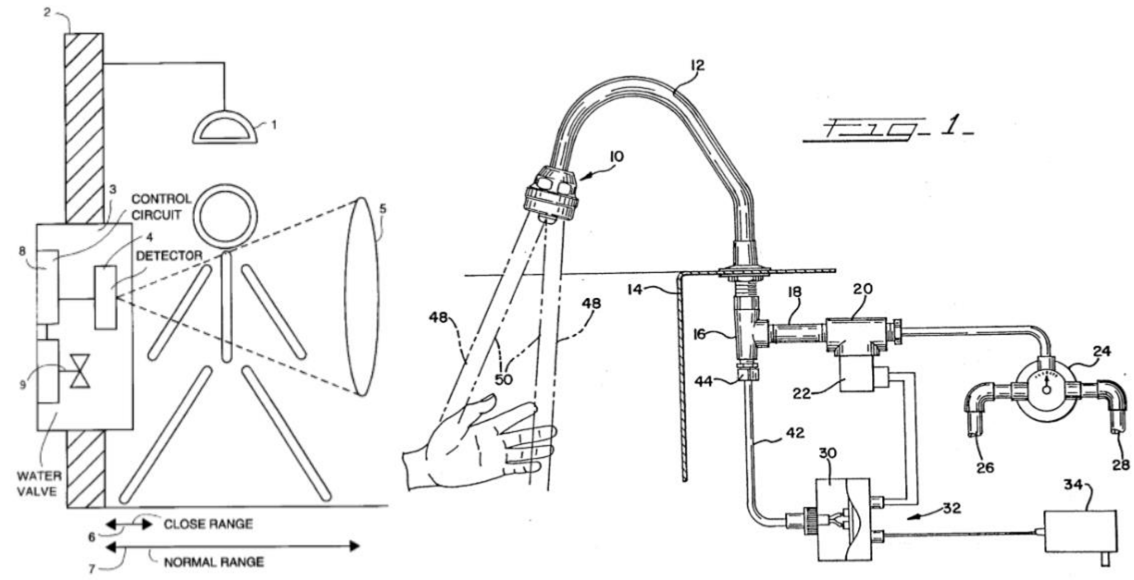

__Figure 6__. Diagrams for U.S. Pat. No. 5,829,072 [18] and US. Pat. No. 4,998,673 [19]

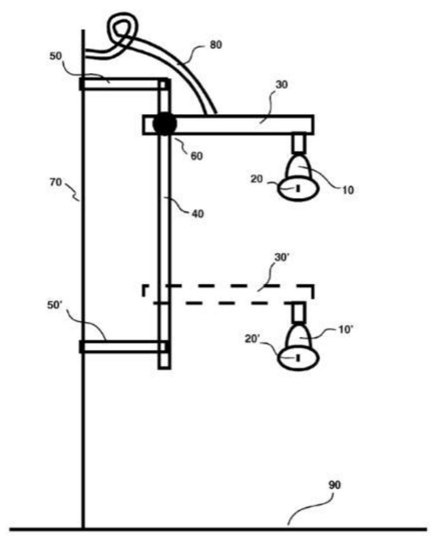

***Figure 7.** Diagram for U.S. Pub. No.: US 2009/0293190 A1 [17]*

2.3 Duration

According to Home Water Works [10] the duration of the shower has a direct effect on water usage. A 20-minute shower will use twice as much water that a 10-minute shower would use if the shower is taken at the same flow rate, therefore reducing the time of showering is proven to conserve water [11].

2.4 Flow Rate

To measure how water is used during a bath, measure the tub's length by width by depth of the water [14]. To get the gallon amount, multiple the bathtub's cubic area by 7.5 if in feet or 231 in inches. There are 7.5 gallons in a cubic foot and one gallon of water is equal to 231 cubic inches of volume. The bath tub in my home is exactly 48 inches long, 20.5 inches wide. If the tub is filled to 9.5 inches deep, there will be 9,348 cubic inches of water in the bath tub which is equal to about 40.5 gallons of water; used all at once. The galloons used per shower relate heavily to the length of the shower and the flowrate of the shower head.

Table 3. *Comparison of different shower method by time in minutes [16]*

Estimated Water Use by Different Bathing Devices and Duration									
	Duration of Event in Minutes								
DEVICE	5	7	10	12	15	17	20	25	30
Tub half-full	20	20	20	20	20	20	20	20	20
Tub full	45	45	45	45	45	45	45	45	45
Whirlpool tub	80	80	80	80	80	80	80	80	80
Shower spas* - small	65	65	65	65	65	65	65	65	65
Shower spas* - large	120	120	120	120	120	120	120	120	120
2.0 GPM Showerhead	10	14	20	24	30	34	40	50	60
2.5 GPM Showerhead	13	18	25	30	38	43	50	63	75
3.0 GPM Showerhead	15	21	30	36	45	51	60	75	90
3.5 GPM Showerhead	18	25	35	42	53	60	70	88	105
4.0 GPM Showerhead	20	28	40	48	60	68	80	100	120
4.5 GPM Showerhead	23	32	45	54	68	77	90	113	135
5.0 GPM Showerhead	25	35	50	60	75	85	100	125	150
5.5 GPM Showerhead	28	39	55	66	83	94	110	138	165
6.0 GPM Showerhead	30	42	60	72	90	102	120	150	180
Color code:	X-Efficient	Efficient		Non-efficient		Wasteful		X-Wasteful	

The chart above rates devices from extra efficient to extra wasteful. It is often perceived that showers use les water, but this chart illustrates that is not always the case. The Alliance for Water Efficiency Organization, states doing activities such was shaving during a shower routine can increase the amount of water used by double [16]. Activities as such are better managed during a bath which has a constant use of water usage as the chart presents.

3. Methodology

The system of methods used in assembly of the design for this research began January 2019. During this time, parts need for this research design were observed up close by visiting the restrooms on the Texas A&M University – Corpus Christi campus (Fig.3-1).

3.1 Infrared (IA) Motion Sensor Shower Assembly

The nonvisible components of an IA motion sensor faucet are pictured in Figure 8. The components include braided water hose connector flexible tubes, a control box that houses the electronic valve and batteries. Some control boxes connect to a power outlet instead of using a battery but according to National Electrical Code requirements [20], the receptacle[7] must be within 36 inches of the outside edge of the sink basin. Due to this code, power outlets should not be near the shower and/or bathtub, so a battery-operated control box was adaptable to this design.

Figure 8. *The underneath of a sink in a Texas A&M University – Corpus Christi restroom.*

To produce an IR motion sensor showerhead, the following items were acquired: control box, flexible water hose, detachable shower head and an IA motion sensor. The control

[7] A receptacle is an electrical outlet into which the plug of an electrical device may be inserted.

box is a 6-volt, direct current (DC) input/output that requires four alkaline AA batteries that are estimated to have a cycle of 2 years at 8,000 cycles per month (Fig.9). Inside the control box is also solenoid valve of 3/8-inch compression inlet and ½-inch national pipe straight mechanical[8] (NSPM) outlet. The IR motion sensor for this project has a range of 4 to 7 inches with a 2-feet cable to allow movement (Fig.10). These parts were ordered from overseas and do not have brands linked to them. The flexible faucet connector was purchase as Lowe's (Fig.11) and the detachable handheld shower head was purchased at Walmart (Fig.12).

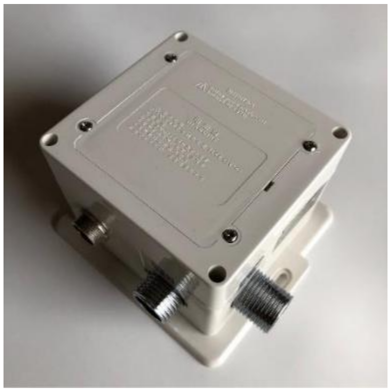

Figure 9. *The control box used for this experiment.*

Figure 10. *The IR motion sensor used for this this experiment.*

[8] American National Standard Pipe Thread standards, often called national pipe thread standards for short, are U.S. national technical standards for screw threads used on threaded pipes and pipe fittings.

Figure 11. *The flexible faucet connector purchased at Lowe's.*

Figure 12. *The parts of the detachable shower head purchased at Walmart.*

3.2 Assembly

The design assembled for this research consists of five major components: Shower head, a 20 inches flexible connector hose, control box, IR motion sensor and the 60 inches hose that was included with shower head. The elbow that came with the shower head is placed at the end of the rod. The flexible connector connects the outlet of the elbow to the inlet of the control box. The 60 inches hose connects the outlet of the control box to inlet of the detachable shower head (Fig.13). The water was turned on at this point to test the connections were water tight. Water ran through the assembly freely since the solenoid valve was not regulate because the four AA batteries nor the IR motion sensor had been added to the control box yet. After adding the four AA batteries to the control box, the IR motion sensor was plugged in to the control box and further testing could continue.

Figure 13. *The components assembled to create the assembly used for testing*

3.3 Testing

The preliminary tests for this assembly were done by placing a hand in front of the IR motion sensor in increments of five seconds until 30 seconds were reached. The assembly performed well. The infrared sensor sensed the hand and regulated the solenoid value to allow the flow of water. Once the hand was moved away from the area the IR motion sensor could sense, the water would stop flowing.

The results later discussed were gathered by allowing myself as the test subject the IR motion sensor would sense. The IR motion sensor was approached from the left side, the right side and from the front. The IR motions sensor can "see" objects in a 4 to 7-inch range. The temperature and pressure of the water was regulated using a single-handle pressure balance valve knob and marked with tape so that at each trial it would be the same (Fig.14). To begin each trial, the knob was turned until it set at the beginning of the tape. A total of 12 trials per time segment (10-minute, 20-minute and 30-minute showers) were recorded; 6 segments without the IR sensor, 6 with the IR sensor. In total, 36 trials were done within the span of two weeks. The results are discussed in section 4.

Figure 14. *The single-handle pressure balance valve knob set in “off” position.*

4. Results

The shower head purchased at Walmart is a 2.5 gallon per minute (GPM) showerhead. This means that every minute that the water is running, 2.5 gallons of water exited the shower head. This rate was used to calculate the water exiting per time segment.

Table 4 shows the results of the gallons per minute before applying the IR sensor. For a 10-minute shower, the average GPM was 25.83; for a 20-minute shower. The average GPM was 51.5; for a 30-minute shower, the average GPM was 75.88. To record the time,

a timer was set for 10-minutes, 20-minutes and 30-minutes. Parallel to this, a video recorder was recording the actual length the water was running used and that is why there are decimals.

Table 5 shows the results of the gallons per minute exiting the shower head after applying the IR motion sensor. The same procedure to keep track of time segments and the length of the water running was used. To have consistency, the same activities were also done for each time segment. For example, the 10-minute segments didn’t include shaving, but the 30-minute segments did.

Table 4. *The gallon per minute used during a shower without the IR motion sensor*

Trial 1	**Time (min)**	10.10	20.20	30.10
	GPM	25.25	50.50	75.25
Trial 2	Time (min)	10.60	21.20	30.20
	GPM	26.50	53.00	75.50
Trial 3	Time (min)	10.20	20.60	31.10
	GPM	25.50	51.50	77.75
Trial 4	Time (min)	10.40	21.10	30.10
	GPM	26.000	52.750	75.250
Trial 5	Time (min)	10.30	20.10	30.40
	GPM	25.750	50.250	76.000
Trial 6	Time (min)	10.40	20.40	30.20
	GPM	26.000	51.000	75.500
Average	**Time (min)**	**10.33**	**20.6**	**30.35**
	GPM	**25.83**	**51.5**	**75.88**

Table 5. *The gallons per minute used during a shower with the IR motion sensor*

Trial 1	Time (min)	5.90	13.00	21.10
	GPM	14.75	32.5	52.75
Trial 2	Time (min)	6.20	12.80	20.80
	GPM	15.50	32.00	52.00
Trial 3	Time (min)	6.00	13.10	20.10
	GPM	15.00	32.75	50.25
Trial 4	Time (min)	5.90	13.00	21.10
	GPM	14.75	32.5	52.75
Trial 5	Time (min)	6.20	12.80	20.80
	GPM	15.5	32.00	52.00
Trial 6	Time (min)	6.00	13.10	20.10
	GPM	15.00	32.75	50.25
Average	**Time (min)**	**6.03**	**12.97**	**20.67**
	GPM	**15.08**	**32.42**	**51.67**

5. Conclusion

It can be observed by comparing the average results of tables 4 and 5 that applying an IR motion sensor to a shower assembly does conserve water. There may be small errors in the results with the techniques used to gather data due to the privacy showering requires. There was also lag time between the timer setting off and moving away from the sensor. The range of the IR sensors need to be larger, 4 to 7-inches was not enough and due to this I used my hand to turn it off and on which limited my use of that hand during testing. After adjustments, the range need to no more than 18 inches for a 36-inch radius shower. Future work also includes having 2-3 adhesive wall mounts allowing the sensor to be adjusted laterally (Fig.15).

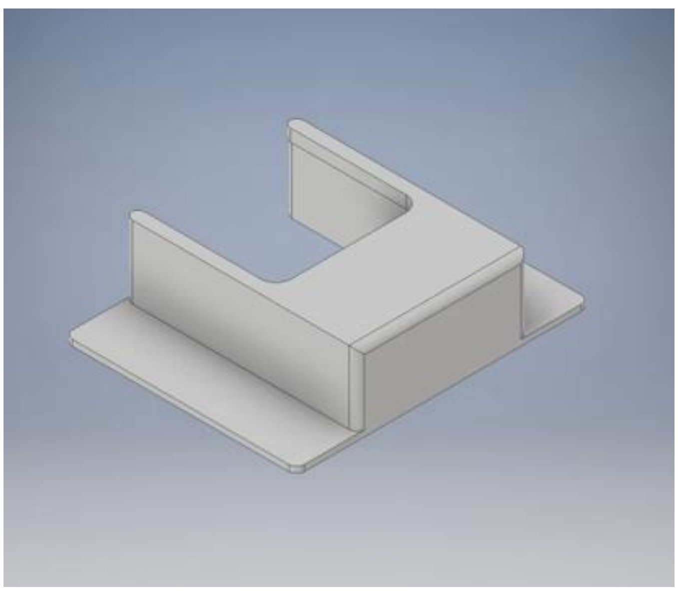

Figure 15. *The wall mount for the IR sensor designed in AutoCAD Inventor*

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