Developing a Prototype for a Microcontroller-Based Coin-Counting Machine

Jean Louis Lance Y. Cabrera, Daenielle D. Cruz, Bentley Andrew Y. Lu
Jorgette Courteney C. Siy, and Clement Y. Ong
De La Salle University Integrated School, Manila

Abstract: Coins have become a significant part of today's economy and are continuously being distributed, along with banknotes, for daily transactions in the most conventional methods. The modernized circulating currency method relies heavily on coin sorting and counting machines to prevent inconsistencies when handling and calculating coins. While the innovation reduces the need for human resources and revolutionizes the way establishments work with large sums of coins, accuracy in differentiating coins becomes an issue in some existing designs. The prototype uses light occlusion and measures the energy of the coin impact to identify the denomination. The prototype shows promise in being able to identify four Philippine coin denominations.

Key Words: coin denomination; coin detection; coin properties; accelerometer sensor; light dependent sensor

1. INTRODUCTION

Coins have had a significant impact on the current currency system of the Philippines. As of March 31, 2019, 31.8 billion pieces of coins valued at 39.5 billion Philippine Pesos have been produced (Bangko Sentral ng Pilipinas, 2019). The Bangko Sentral ng Pilipinas (BSP) ensures that the supply and division of coins are sufficient and non-repetitive (Chipongian, 2019). According to Doza (2018), there was a new update on the currency of the Philippines, which is called the "New Generation Currency (NGC)." The BSP made new coins having millimeters of 20, 16, 15, 23, 25, 27 for the diameters of 25-Centimo, 5-Centimo, 1-Centimo, 1-Peso, 5-Peso, and 10-Peso (Doza, 2018). These new coins have new security features, consisting of an electromagnetic signature embedded and considered (Doza, 2018; Rogers & Thomas, 2017).

As coins are highly used in the country, coin counterfeiters have constantly been trying to abuse this. There are currently two false identification systems used in coin counter machines: mechanical and technological (Delgado, n.d; Hu, n.d.). According to Hu (n.d.), mechanical coin tester mechanisms check the coin's width and weight to determine its denomination and use electromagnetism to identify its coin denomination. According to Delgado (n.d.), technological coin tester mechanisms use image capturing technology or Circular Hough Transform (CHT) to identify its authenticity as it would find all the possible radii to locate the placement of the coin. Afterward, it would utilize the Fisher Linear Discriminant analysis and electromagnetism to identify the coin denominations (Delgado, n.d.). At present, coin counting machines are still utilizing false identification systems to increase their security and avoid counterfeit coins (Chipongian, 2019). However, according to ABS-CBN News (2017), it was not until March of 2018 when the Light Rail Manila Corporation (LRMC) updated its ticket vending machines four months after the release of the new 5-peso coin.

To solve the problem, a new prototype for a coin-counting machine was proposed. This prototype has an ingenious way of identifying Philippine coins, despite designs varying throughout the years, that are efficient, accurate, and made with quality materials to better its performance. The researchers aim to implement non-image sensing technologies to develop a software that could distinguish coin denominations such as 1-Peso, 5-Peso, 10-Peso, and 20-Peso, based on the sensor data. Coins deliberately altered (mutilated or deformed), damaged (oxidized, worn down), commemorative coins, and centavos cannot be classified or identified as acceptable. The researchers would evaluate the prototype's consistency and speed in distinguishing these various coin denominations.

The findings of this study will greatly benefit those who frequently utilize coins. This prototype serves as a guide for people to improvise ways to identify and distinguish Philippine coins. Also, establishments that usually need to input coins will have a more convenient time as determining coins of different denominations would become timesaving and better in terms of accuracy. Besides this, future researchers can further their knowledge with this prototype acting as a basis for refinement of future works.

2. METHODOLOGY

2.1 Light Dependent Sensor

This sensor consists of a light dependent resistor (LDR) and a light-emitting diode (LED) set to face each other, wherein an uploaded code will solve for the time occluded as the coin passes through (Figure 1). Ten trials were done per coin denomination. After the first ten trials, changes were made to make coin drop more consistent: the use of a coin dropper, the height drop setting (6 cm), and the use of an LM324 following a circuit diagram (Figure 2).

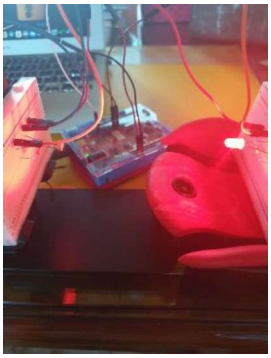

Figure 1. Initial Setup for Light Dependent Resistor.

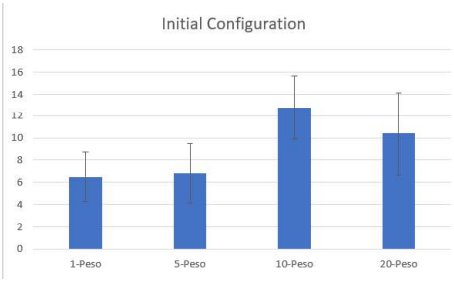

Figure 2. Initial results of Light Dependent Resistor.

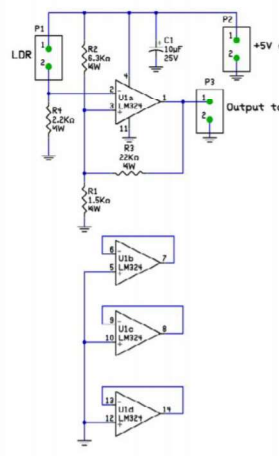

Figure 3. Circuit Diagram for Light Dependent Resistor.

2.2. ACCELEROMETER SENSOR

This MPU-6050 accelerometer is attached to a plate and anchored to two boxes. When a coin is dropped on the plate, the vibrations will be collected using an uploaded code (Figure 4). Ten trials were made per coin denomination. After the first five attempts, the setup for the MPU-6050 was modified to minimize the vibrations and absorb the initial impact made by the coin (Figure 5). The MPU-6050 remained attached to the plate in the redesigned setup — tilted to an angle and placed on the floor. Furthermore, a small chair was positioned with a red circular mark to indicate the height wherein the coin will be dropped (Figure 6).

Figure 4. Initial Configuration for Accelerometer Sensor.

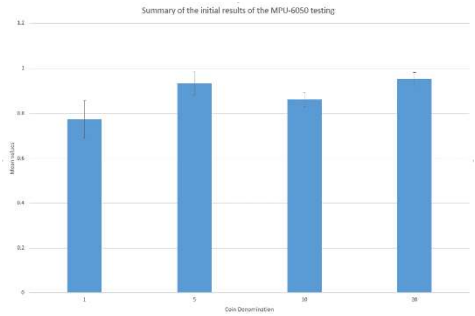

Figure 5. Summary of Initial Results of the Accelerometer Results on the Y-axis.

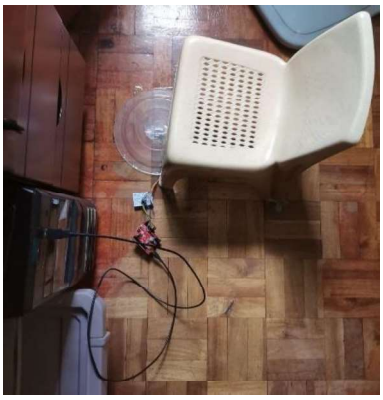

Figure 6. Final Configuration for the MPU-6050 Sensor.

2.3. Prototype Testing

After conducting and recording the light dependent sensor and accelerometer sensor trials, both sensors were combined into one prototype (Figure 7). Nevertheless, the prototype utilized the same height (6 cm) used for dropping the coin with a coin dropper, while the accelerometer sensor utilized the chair with a circular mark. There were slight changes to enhance the prototype's performance: the addition of another chair, cardboard (to hold the light dependent sensors), and cardboard (on top of the accelerometer sensor).

Figure 7. Prototype Setup.

3. RESULTS AND DISCUSSION

3.1. Light Dependent Sensor

After several trials and alterations, results showed gradual improvements from each adjustment made (Table 1). The light dependent sensor's initial trial had a minimum standard deviation of 2.202, which then changed to 0.539 in the final results. The mean values also went from an indistinguishable set of numbers to a distinguishable and concise set of numbers. Furthermore, coin denominations such as one and five overlapped, while denominations ten and twenty were not overlapping (Figure 8).

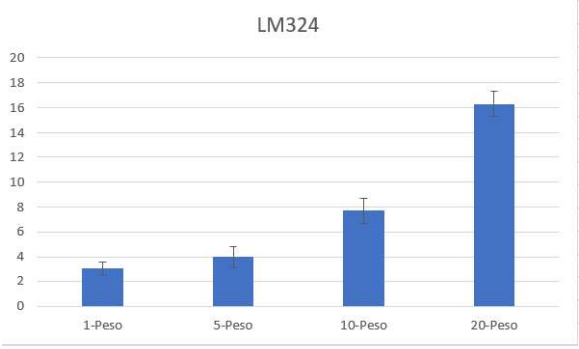

Figure 8. Final results of the light dependent sensor.

Table 1. Results of the Changes of Light Dependent Sensor

		1-Peso	5-Peso	10-Peso	20-Peso
Initial Configuration	Mean	6.5	6.8	12.8	10.4
	Standard Deviation	2.202	2.676	2.891	3.720
Addition of a ruler	Mean	5.9	8.3	10	15.8
	Standard Deviation	1.135	1.552	1.483	1.720
Addition of a coin dropper	Mean	10	10.6	12.2	8.2
	Standard Deviation	0.755	1.114	1.400	1.077
Final Setup	Mean	3.1	4	7.7	16.3
	Standard Deviation	0.539	0.831	1.00	1.00

3.2. Accelerometer sensor

Based on the final results of the MPU-6050 trials, it can be seen that the significant impact of the coin would be on the Y-axis as it is the focal point of the drop, having the values vary significantly (Table 2). However, the X and Z values differ from each denomination. These values were caused by the plastic plate's movement horizontally when impacted by the drop of the coin; therefore, the Y value was considered.

Table 2. Final Results of the MPU-6050 Testing

	Trials				
1-Peso	1	2	3	4	5
X	3.78	4.07	4.78	4.00	3.56
Y	0.22	-0.27	0.08	0.05	0.22
Z	-9.73	-11.42	-14.95	-10.96	-10.55
	6	7	8	9	10
X	4.35	4.26	3.75	3.75	1.26
Y	-0.07	0.06	-0.25	-0.04	-0.25
Z	-12.65	-11.96	-11.19	-10.21	-12.98
5-Peso	1	2	3	4	5
X	3.44	3.20	5.97	3.77	3.11
Y	-0.22	-0.15	-0.34	0.06	-0.50
Z	-10.27	-9.47	-17.73	-11.26	-8.78
	6	7	8	9	10
X	3.91	4.20	4.77	4.30	3.09
Y	-0.10	-0.44	-0.21	-0.47	-0.33
Z	-11.33	-12.97	-11.01	-14.04	-10.21
10-Peso	1	2	3	4	5
X	3.65	3.77	4.29	4.32	3.80
Y	-0.35	-0.39	-0.44	-0.54	-0.28
Z	-11.61	-10.41	-11.68	-12.51	-10.44
	6	7	8	9	10
X	4.57	6.55	4.98	3.32	4.15
Y	-0.42	-1.28	-1.36	-0.62	-1.11
Z	-12.70	-17.44	-16.54	-10.77	-15.22
20-Peso	1	2	3	4	5
X	4.65	4.25	5.01	4.15	5.83
Y	-2.65	-3.58	-2.29	-1.07	-1.88
Z	-10.90	-15.35	-8.32	-11.79	-11.05
	6	7	8	9	10
X	2.68	3.56	4.50	4.47	3.46
Y	-3.32	-1.96	-1.56	-1.05	-1.26
Z	-3.65	-6.68	-10.55	-8.05	-7.53

There were more distinct and wide-spread means than the initial results; however, this could be decreased by dropping the coin in a consistent manner (Table 3 & Figure 9).

Table 3. Summary of the Final Results of the MPU-6050 Configuration

Coin	Mean	Standard Deviation
1-Peso	-0.025	0.175
5-Peso	-0.270	0.170
10-Peso	-0.679	0.388
20-Peso	-2.060	0.850

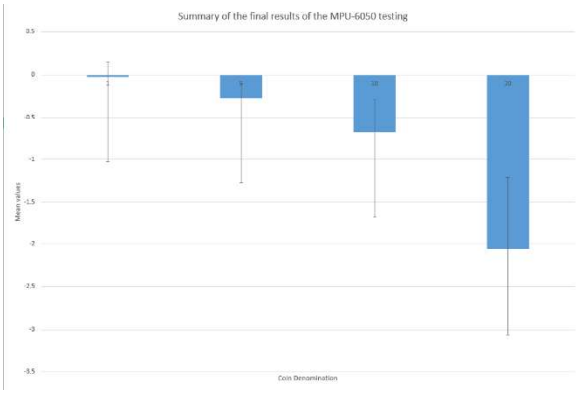

Figure 9. Summary of the Final Results of the MPU-6050 Testing.

3.3. Prototype Testing

The final results of both the light dependent sensor and the accelerometer sensor were utilized as a guide to determine the coin denomination being dropped. However, the results were not similar to the final results due to the variety of ways in coin dropping. Hence, another set of trials were conducted to obtain the sensors' data with the combined setup (Table 4). These values consisted of the time occluded by the coin, the peak value of the y-axis, and the average values around the peak of the y-axis (consists of one value before the peak, the peak itself, and three values after the peak).

Table 4. Results of Prototype Testing

	Trials				
1-Peso	1	2	3	4	5
Time Occluded	8	8	8	8	9
Peak Value	5.75	5.64	5.45	4.73	6.21
Average Values around the Peak	5.43	3.19	3.32	3.30	4.22
	6	7	8	9	10
Time Occluded	8	8	8	8	9
Peak Value	4.61	6.30	6.15	4.68	3.77
Average Values around the Peak	2.46	3.65	3.76	2.89	2.84
5-Peso	1	2	3	4	5
Time Occluded	9	9	10	9	10
Peak Value	6.93	7.58	9.25	7.77	9.10
Average Values around the Peak	4.04	4.79	5.59	4.77	5.79
	6	7	8	9	10
Time Occluded	10	10	10	9	11
Peak Value	9.47	7.31	8.34	6.71	9.68
Average Values around the Peak	5.27	4.64	5.59	3.85	5.88
10-Peso	1	2	3	4	5
Time Occluded	12	12	13	11	13
Peak Value	9.61	7.74	7.77	7.21	9.72
Average Values around the Peak	6.28	4.40	4.82	4.55	5.99
	6	7	8	9	10
Time Occluded	12	14	13	12	12
Peak Value	7.26	8.25	9.88	7.75	8.50
Average Values around the Peak	4.44	4.36	5.97	4.92	5.08
20-Peso	1	2	3	4	5
Time Occluded	16	16	16	18	15
Peak Value	11.23	11.05	18.88	11.00	11.05
Average Values around the Peak	6.48	6.86	6.09	6.68	7.34
	6	7	8	9	10
Time Occluded	16	16	18	16	18
Peak Value	12.06	10.66	11.92	14.57	12.09
Average Values around the Peak	7.27	4.77	6.09	8.54	7.86

Table 5. Summary of the Results of Prototype Testing

	1-Peso	5-Peso	10-Peso	20-Peso
Peak Value: Mean	5.3385	8.214	8.369	12.451
Peak Value: SD	0.8025	1.0454	0.9690	2.3900
Peak Value: Range	4.68 to 6.30	6.71 to 9.47	7.21 to 9.88	10.66 to 18.88
Average Values around the Peak: Mean	3.506	5.021	5.081	6.881
Average Values around the Peak: SD	0.7994	0.6807	0.6946	0.9674
Average Values around the Peak: Range	2.84 to 4.22	3.85 to 5.88	4.40 to 5.99	6.48 to 8.54
Time Occluded: Mean	8.2	9.7	12.4	16.5
Time Occluded: SD	0.4	0.6403	0.8	1.0247
Time Occluded: Range	8 to 9	9 to 11	11 to 14	15 to 18

The summary of the results had shown that the discriminants' hierarchy, from highest to lowest, is the time occlusion, then average values around the peak then peak values (Table 5). With this in mind, the values were simulated in a software that could determine coin denominations (Table 6).

Table 6. Confusion Matrix for Software Simulation

	Coin Reading				
Coin	1-Peso	5-Peso	10-Peso	20-Peso	Not Classified
1-Peso	10	0	0	0	0
5-Peso	0	9	1	0	0
10-Peso	0	0	9	0	1
20-Peso	0	0	0	10	0

Based on the values of Table 6, the simulation showed that the 1-Peso and 20-Peso simulations were correctly identified ten times.

Additionally, the 5-Peso and the 10-Peso simulation were both correctly identified nine times, having one incorrect result as the 5-Peso was recognized as a 10-Peso coin and the 10-Peso coin was not classified. Furthermore, this code was used to simulate ten more trials (Table 7).

Table 7. Confusion Matrix for the Live Simulation

	Coin Reading				
Coin	1-Peso	5-Peso	10-Peso	20-Peso	Not Classified
1-Peso	8	1	0	0	1
5-Peso	0	7	2	0	1
10-Peso	0	1	7	0	2
20-Peso	0	0	0	10	0

It is evident that the simulation can be used to identify coin denominations as it identified 20-Peso coins ten times, 10-Peso and 5-Peso seven times, and 1-Peso eight times, respectively. After further alterations in the code and the setup, the new setup and result can be seen in Figure 10 and Table 8.

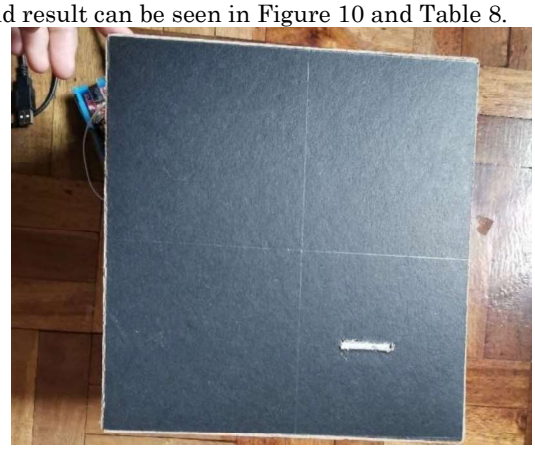

Figure 10. Final Setup for the Prototype Testing.

Table 8. Confusion Matrix for the Final Setup

	Coin Reading				
Coin	1-Peso	5-Peso	10-Peso	20-Peso	Not Classified
1-Peso	100	0	0	0	0
5-Peso	0	97	0	0	3
10-Peso	0	0	100	0	0
20-Peso	0	0	0	100	0

As the results of the trials that can be seen in Table 8 improved, fake coins were tested whether they would be detected as any of the denominations. The fake coins that were used were 5 cents, 10 cents, 25 cents, 10 Malaysian sen, a washer, a bigger washer, and a button. The 5 cents, the washer, the bigger and the button were rejected by the setup mechanically. The washer and the bigger washer were wrapped with aluminum foil and were tested again to check whether it was not detected because of the whole between it. The washer was again rejected by the setup, while the bigger washer was detected but not classified as any coin. On the other hand, the other coin samples were detected but not classified as any denomination. The result can be seen in Table 9.

Table 9. Confusion Matrix for other coin samples

	Coin Reading				
Coin	1-Peso	5-Peso	10-Peso	20-Peso	Not Classified
5-Cent	N/A	N/A	N/A	N/A	N/A
10-Cent	0	0	0	0	100
10 Malaysia Sen	0	0	0	0	100
25-Cent	0	0	0	0	100
Bigger washer wrapped in aluminum foil	0	0	0	0	100
Bigger washer	N/A	N/A	N/A	N/A	N/A
Button	N/A	N/A	N/A	N/A	N/A
Washer	N/A	N/A	N/A	N/A	N/A
Washer wrapped in aluminum foil	N/A	N/A	N/A	N/A	N/A

4. CONCLUSIONS

The prototype setup can distinguish four Philippine coin denominations. Adjustments made to the sensors, electronically and in software, coupled with changes in the mechanical design and layout for the coin drop, contributed to the increasing ability of the prototype to identify the coins. The prototype setup can also distinguish real coins from fake coins.

5. REFERENCES

ABS-CBN News. (2017). LRT-1: ticket vending machines to accept new coins in March 2018.

ABS-CBN News. https://news.abs-cbn.com/business/12/22/17/lrt-1-ticket- vending-machines-to-accept-new-coins-in-march-2018

Bangko Sentral ng Pilipinas. (2019). Frequently asked questions [PDF FILE]. http://www.bsp. gov.ph/downloads/Publications/FAQs/banknotes.pdf

Chipongian, L. (2019). BSP to put coin-counting machines in groceries. Manila Bulletin. https://business.mb.com.ph/2019/07/16/bsp-to-put-coin-counting -machines-in-groceries

Delgado, D. (n.d.). Automatic coin and bill detection [PDF FILE].
https://web.stanford.edu/class/ee368/Project_Autumn_1617/Reports/report_delgado.pdf

Doza, E. (2018). BSP ensures security features in new coins. Philippine Information Agency. https://pia.gov.ph/news/articles/1007048

Hu, D. (n.d.). How a coin tester works. Report on how things work. https://web.mit.edu/2.972/ www/reports/coin_tester/coin_tester.htm

Rogers, S., & Thomas, R. (2017). Detection of the security feature in the new £1 coin [PDF
FILE]. https://www.matlabexpo.com/content/dam/mathworks/mathworks-dot-com /images/events/matlabexpo/uk/2017/detection-of-security-feature-in-new-1-coin.pdf