Universiti Malaysia PAHANG
Engineering • Technology • Creativity

JOURNAL OF MODERN MANUFACTURING SYSTEMS AND TECHNOLOGY

Homepage: http://journal.ump.edu.my/jmmst
ISSN (Online): 2636-9575

Development of Product Resource Inventory Control Using Forecasting In 'SMED'

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Articles Info:
Received **22 June 2018**
Received in revised form **17 Aug 2018**
Accepted **11 Sept 2018**
Available Online **13 Sept 2018**

Keywords:
PSS
Forecasting
Industry 4.0
Inventory control
SMED

ABSTRACT

Industry 4.0 known as "Fourth Industrial Revolution" and also "smart manufacturing" is the current trend of the manufacturing organization. There are four main components for Industry 4.0 which are Internet of Things (IoT), Cyber Physical Systems (CPS), Internet of Services (IoS) and Smart Factory. Product service system (PSS) is a system that combine product and service; to fulfill customer demand and increase their satisfaction level. The main objective of inventory control is to prevent storage overload and ensure storage always have sufficient supply for the customer. By adding sensor, the inventory in storage can be counted and controlled. The output from the sensor can be displayed on the computer and the operator can look out the storage status. Forecasting in inventory can predict the trend of the inventory in future. This allow operator to keep tracking on their reorder point and make sure the inventory never run out.

INTRODUCTION

Industry 4.0 known as "Fourth Industrial Revolution" and also "smart manufacturing" is the current trend of the manufacturing organization. Industry 4.0 introduces smart factory where most of the process in the factory are replace by artificial intelligence, mathematical algorithm, robotics and others. There are four main components for Industry 4.0 which are Internet of Things (IoT), Cyber Physical Systems (CPS), Internet of Services (IoS) and Smart Factory.

The Cyber Physical System (CPS) is a new generation system with embedded computation and physical capabilities which can be control and monitor. Control system design is a good example for CPS. The outputs of control system are determined by the mathematical modelling and the input requirement. The recent developments of CPS are more on sensors, data acquisition and computer networks which push the industries to higher level of technologies. The data generated from CPS becoming large and hence the

machine we design need to be more intelligence and fast so that these large volume of data can be process without any delay. Internet of Things (IoT) is a network form by CPS.

Due to vast develop of global manufacturing industry; the products are produce in tremendous speed with better quality to meet the customer demand. Thus, it is not surprise that the global manufacturing GDP share had decline every year. In order to increase competiveness against other industry, many industries are started to include service into their product which known as servitization. Vandermerwe and Rada (1988), defined servitization: the increased offering of fuller market packages or 'bundles' of customer focussed combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings. Servitization involve to parties: customer who seek for solution and service provider to develop and provide solution the customer. To increase the profit earn, the product is offered along with the service to the customer and hence become product service system (PSS).

Inventory is described as any property own by a company; it could be raw material, spare parts, finished good etc. Control is one of the managerial functions, it can be planning, organizing, managing etc. The main objective of inventory control is to ensure that the company have sufficient item to be ready to process without any delay of time. The most common and easiest way to control and store inventory is using ABC classification. Traditional ABC classification, consider one criterion and sometimes one criterion is not enough to classify the item. This lead to another solution which is classifies the item using multiple criteria. Analytic hierarchy process (AHP) methodology considers the qualitative and quantitative criteria to classify the inventory.

As define in Cambridge dictionary, forecast is a statement which assume what will likely to be happen in future. Forecasting in industry is using their historical data and predicts how much budget they need to spend so that their future company development will not be affected. Nowadays, every industry should have their own forecast system on their inventory to prevent overstock or understock. Inventory forecasting can be divided into two parts which are qualitative and quantitative methods. Qualitative method doesn't have its own fix calculation. It is calculated by using few factors such as market analysis, basic assumption of market price, and so on. Quantitative method is based on fixed equation and data from the past to predict the trend of the inventory. In this chapter, we will only discuss about the quantitative method because we are using data from the past which is more reliable compare to qualitative.

METHODOLOGY

This project includes two parts which are hardware and software. The hardware part is built using Arduino microcontroller board interface with ultrasonic sensors. The sensors will receive data from the rack and give output to the software part.

The software part is a graphical user interface (GUI) made by Visual Studio. The GUI will display data obtained from the sensors. The GUI will also have its forecasting feature which allow user to forecast their inventory. The advantage of using Arduino and Visual Studio:

1. Open source and programming code easy to understand;
2. Materials are cheap and cost saving;
3. Can be modified easily depend on requirement;
4. Low maintenance fee.

The ultrasonic sensors are connected with Arduino Uno as shown in Figure 1. The Trig pins are connected to digital pin 3,5,7,9 and Echo pins are connected to digital pin 2,4,6,8. The flow of inventory management system for this project is shown in Figure 2. First, the sensors will sense the quantity of item on the rack and then send data to the Arduino. Arduino will then process the data and display on the GUI on computer. Then, user can observe the data and make decision whether to increase or decrease the item on rack. Finally, user can save the data and upload to their company database as future reference. Next, we will discuss the three quantitative methods in forecasting which are:

1. Exponential smoothing method
2. Exponential moving average
3. Simple moving average

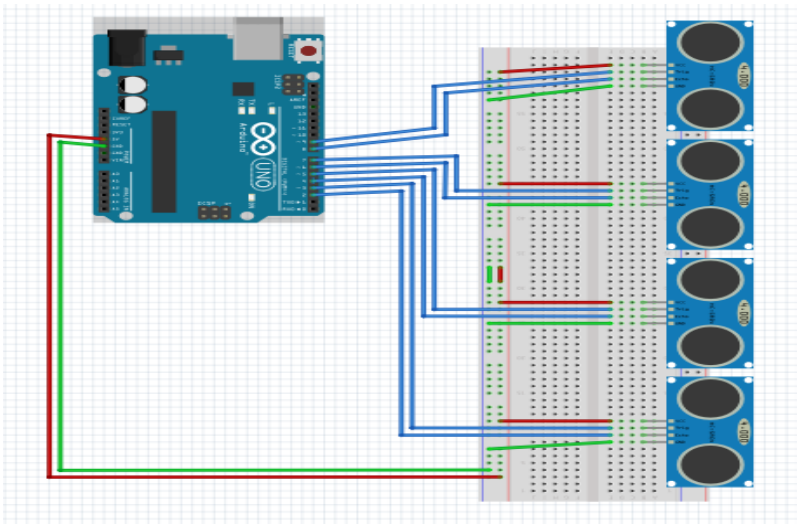


Figure 1: Circuit for ultrasonic interface with Arduino

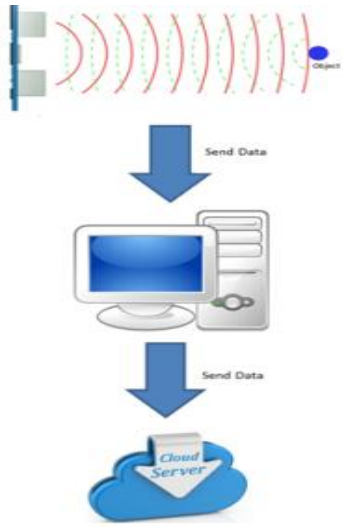


Figure 2: Overview of inventory management system.

I. Exponential Smoothing

This method tends to smooth the graph so that the trending behavior can be observed. So, exponential smoothing method uses simple calculation to forecast the inventory. The equation of exponential smoothing method is given as below:

The first value of forecast, X_0 will be the sum of quantity divided by time.

$$X_0 = \frac{Sum\ of\ quantity}{Time\ series, t} \quad (1)$$

The next value of forecast, X_n will be calculated by adding last value X_{n-1} and multiply alpha value with the difference of previous actual quantity Z_{n-1} with X_{n-1}. Equation below summarizes the exponential smoothing method.

$$X_n = X_{n-1} + \alpha * (Z_{n-1} - X_{n-1}) \quad where\ n > 0 \tag{2}$$

II. Exponential Moving Average (EMA)

Exponential moving average is use to reduce lag or delay of forecasting. For EMA, the forecast value will have less lag and the trend is reacting faster. Same as exponential smoothing method, EMA also have its own alpha value. The alpha value changes depend on the number of time period used as sample.

$$\alpha = 2 / ((Time\ period + 1)) \tag{3}$$

The first forecast value is the average of the period use as sampling. If we are using three period, the X0 will be (a+b+c)/3. The general formula will be:

$$X_0 = \frac{Total\ quantity\ of\ n\ period}{Time\ period, n} \tag{4}$$

The Z_n is the value of today actual stock. The next forecast value X_n will be:

$$X_n = \alpha * (Z_n - X_{n-1}) + X_{n-1} \quad where\ n > 0 \tag{5}$$

III. Simple Moving Average (SMA)

Simple moving average is a method that calculates using the closest value of the time period. To make it simple, it is an average of subset any time period. More often, company using this method to see the trend of product. As it name "moving average" stated, the forecast value will keep on update by using the next number of period as guide. This cause the forecast will always move forward along the time. The equation of SMA is given as below.

$$X_n = \frac{Z_n + Z_{n+1} + Z_{n+2} \ldots}{number\ of\ actual\ value, Z} \tag{6}$$

Below is the example calculation using SMA.
Given eight days data: 3, 4, 5, 6, 7, 8, 9, 10
First four days of SMA: (3 + 4 + 5 + 6)/ 4 = 4.5
Second four days of SMA: (4 + 5 + 6 + 7)/4 = 5.5
Third four days of SMA: (5 + 6 + 7 + 8)/4 = 6.5

RESULTS AND DICUSSIONS

I. Exponential Smoothing

Table 1: Forecast quantity using Exponential Smoothing with different a value

PERIOD	ACTUAL STOCK	FORECAST QUANTITY WITH α VALUE		
		0.20	0.50	0.80
JAN	102.00	128.75	128.75	128.75
FEB	115.00	123.40	115.38	107.35
MAR	118.00	121.72	115.19	113.47
APR	127.00	120.98	116.59	117.09
MAY	121.00	122.18	121.80	125.02
JUN	140.00	121.94	121.40	121.80
JULY	150.00	125.56	130.70	136.36
OCT	155.00	130.44	140.35	147.27
SEP	142.00	135.36	147.67	153.45
OCT	133.00	136.68	144.84	144.29
NOV	120.00	135.95	138.92	135.26
DEC	122.00	132.76	129.46	123.05

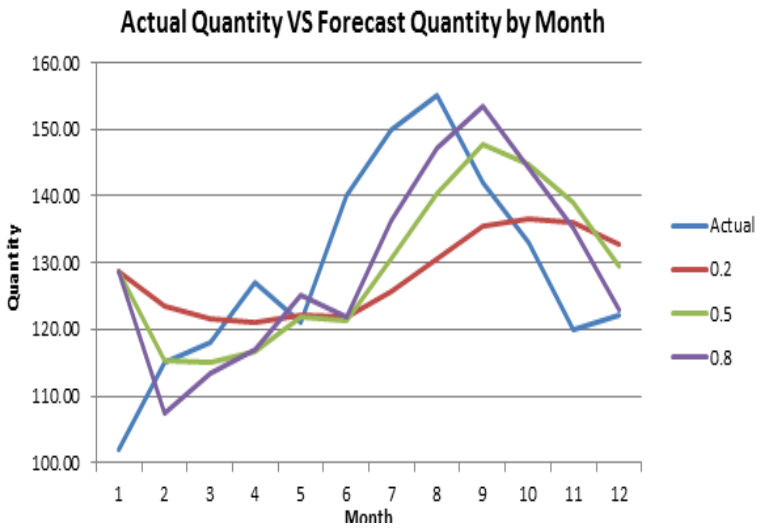


Figure 3: Graph of Actual Quantity VS Forecast Quantity using Exponential Smoothing

From the graph pattern in Figure 3, the lower the alpha value the smoother the graph become. In addition, the forecast trend is delay by one month and has the same pattern with the actual. To compare with other two methods, we are using data started from April.

II. Exponential Moving Average (EMA)

Table 2: Forecast value using Exponential Moving Average

PERIOD	ACTUAL STOCK	FORECAST STOCK	|ERROR|	% ERROR
JAN	102.00			
FEB	115.00			
MAR	118.00			
APR	127.00	111.67	15.33	12.07
MAY	121.00	116.33	4.67	3.86
JUN	140.00	128.17	11.83	8.45
JULY	150.00	139.08	10.92	7.28
OCT	155.00	147.04	7.96	5.13
SEP	142.00	144.52	2.52	1.78
OCT	133.00	138.76	5.76	4.33
NOV	120.00	129.38	9.38	7.82
DEC	122.00	125.69	3.69	3.02

Figure 2 using Exponential Moving Average method causes the value has less lag compare to Exponential Smoothing method. The forecast value increase and decrease at the same month with the actual value.

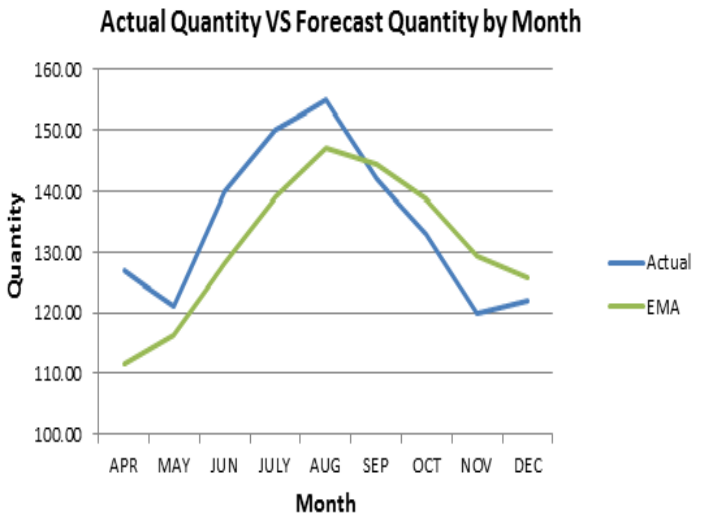


Figure 4: Graph of Actual Quantity VS Forecast Quantity using Exponential Moving Average

III. Simple Moving Average (SMA)

Table 3: Forecast quantity using Simple Moving Average

PERIOD	ACTUAL STOCK	FORECAST STOCK	|ERROR|	% ERROR
JAN	102.00			
FEB	115.00			
MAR	118.00			
APR	127.00	111.67	15.33	12.07
MAY	121.00	120.00	1.00	0.83
JUN	140.00	122.00	18.00	12.86
JULY	150.00	129.33	20.67	13.78
OCT	155.00	137.00	18.00	11.61
SEP	142.00	148.33	6.33	4.46
OCT	133.00	149.00	16.00	12.03
NOV	120.00	143.33	23.33	19.44
DEC	122.00	131.67	9.67	7.92

Figure 5 using Simple Moving Average, the forecast value seems become dull and does not react the same with the actual value. In addition, the graph pattern is similar to Exponential Smoothing method.

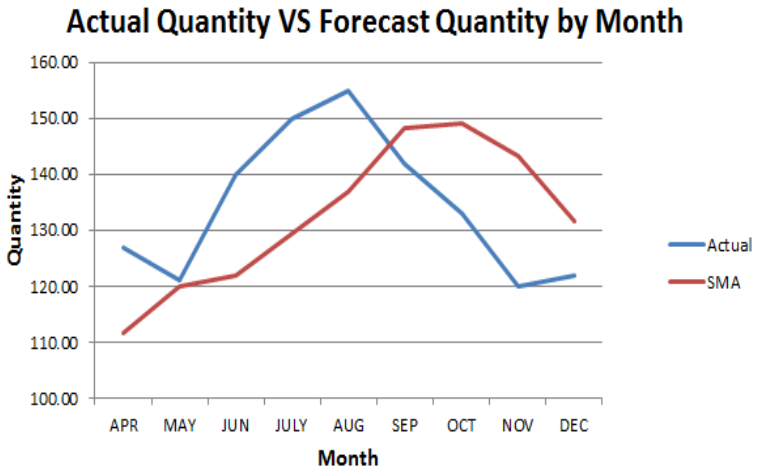


Figure 5: Graph of Actual Quantity VS Forecast Quantity using Simple Moving Average

IV. Comparison with all three method

Table 4: Comparison of forecast value of exponential smoothing, EMA and SMA

PERIOD	ACTUAL	EX. SM.	SMA	EMA
JAN	102.00			
FEB	115.00			
MAR	118.00			
APR	127.00	116.59	111.67	111.67
MAY	121.00	121.80	120.00	116.33
JUN	140.00	121.40	122.00	128.17
JULY	150.00	130.70	129.33	139.08
OCT	155.00	140.35	137.00	147.04
SEP	142.00	147.67	148.33	144.52
OCT	133.00	144.84	149.00	138.76
NOV	120.00	138.92	143.33	129.38
DEC	122.00	129.46	131.67	125.69

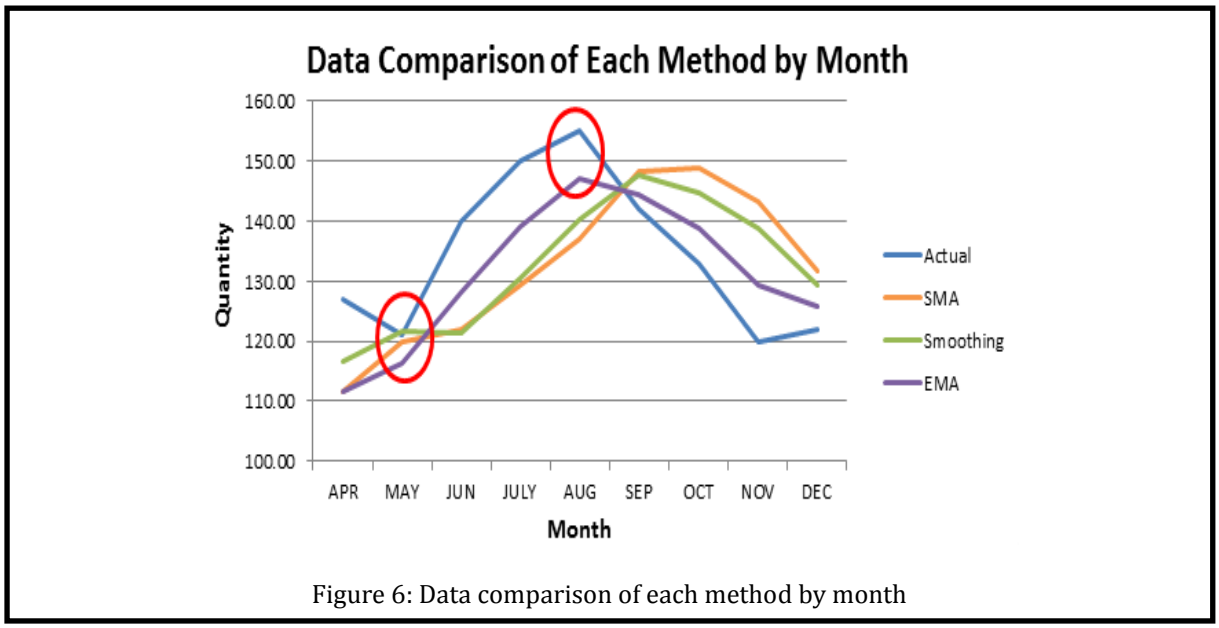


Figure 6: Data comparison of each method by month

In Figure 6 EMA have less lag and respond faster compare to exponential smoothing and SMA method. The two red circle the point when the trend is started to change. EMA react the same as the actual which rise at May and drop at August. However, SMA and smoothing started to rise at June and decrease at September.

Table 5 shows the average percentage error for each month of Exponential Moving Average is the lowest compare to other two methods. In addition, Figure 6 also shows that EMA have less lag and react faster. Hence, we are applying EMA for our software part.

IV. Software

The data can be input manually for code item, category and location whereas the data in stock category is record from the ultrasonic sensor. The flow of the process is shown in Figure 7-12.

Figure 7: Example of data record from hardware

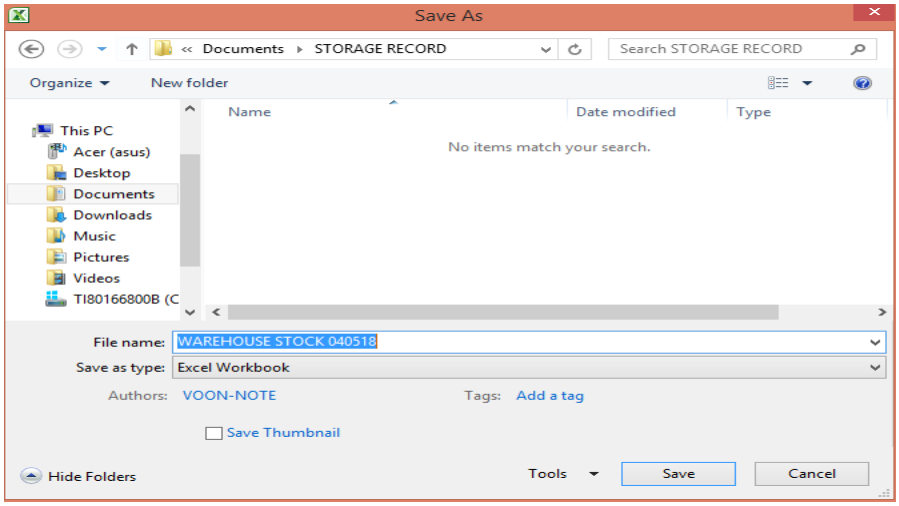


Figure 8: Save data in excel format as record

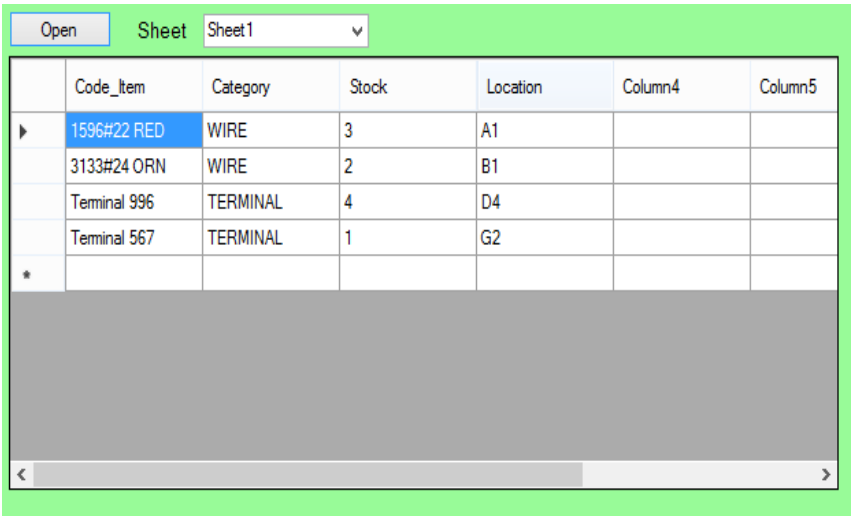


Figure 9: Reading data that had save in excel format

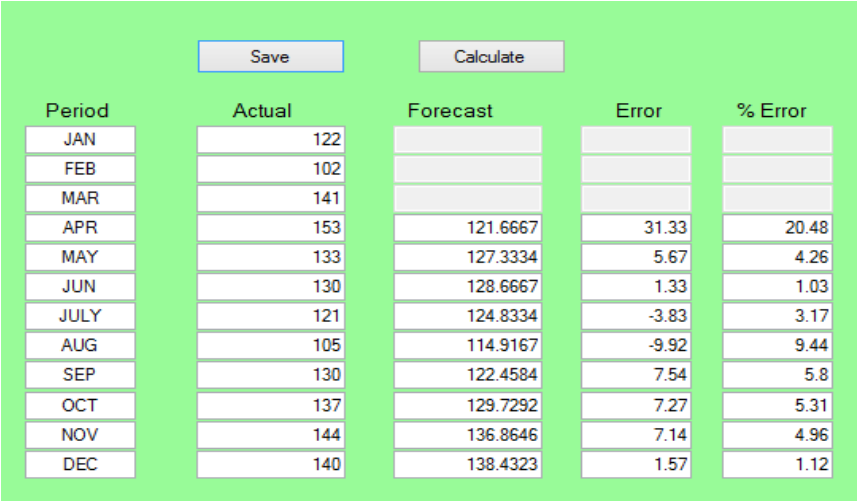
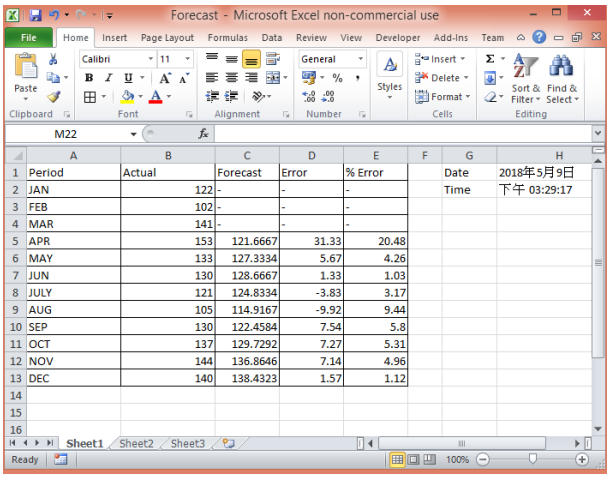


Figure 10: Forecast feature using EMA method

After data is input in the actual value column, the user can click the calculate button to generate forecast value, error and % error. Then, user can save the data into Excel format. Lastly, the user can generate graph from the data input and see the trend of the forecast and actual value.



	A	B	C	D	E	F	G	H
1	Period	Actual	Forecast	Error	% Error		Date	2018年5月9日
2	JAN	122	-	-	-		Time	下午 03:29:17
3	FEB	102	-	-	-			
4	MAR	141	-	-	-			
5	APR	153	121.6667	31.33	20.48			
6	MAY	133	127.3334	5.67	4.26			
7	JUN	130	128.6667	1.33	1.03			
8	JULY	121	124.8334	-3.83	3.17			
9	AUG	105	114.9167	-9.92	9.44			
10	SEP	130	122.4584	7.54	5.8			
11	OCT	137	129.7292	7.27	5.31			
12	NOV	144	136.8646	7.14	4.96			
13	DEC	140	138.4323	1.57	1.12			
14								
15								
16								

Figure 11: Data saved from GUI and displayed in Excel

Figure 12: Graph generated from GUI

CONCLUSIONS

Every industry will need to arrange their supply in order to meet the demand of their customer. Over estimating will cost burden to the supplier and under estimating might cause problem to the supply chain. Hence, the supplier or manufacturer should plan and control their inventory to minimise the losses. The perfect control toward inventory is the input equal to the output. However, in real situation it is impossible to achieve that condition. What we can do is keeping the old data and keep on analyse. The more data collected and analysed, the more accurate to forecast and control the inventory.

In this project, only equation is applied to forecast the inventory. In real situation, the company will use many methods such as market price, customer survey and others to make judgement on purchasing the supplies. This is because different supplier will have their own prices for their product.

FUTURE WORKS

The hardware for this project has its own limitation on ports. In the early stage, we had planned to add security system such as adding a RFID system to prevent someone stealing the product on rack. The hardware can be improved using Arduino Mega microcontroller which has more ports compare to Arduino Uno. This can let the hardware to be install with various sensor can display on the GUI. The GUI can be improved by adding more features for the customer to use. A proper survey can be done to know what feature is needed to improve the GUI.

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