ETM ENGINEERING & TECHNOLOGY MANAGEMENT

Will Camera Phones ever replace the Compact Cameras?

(Forecasting of Digital Image SensingTechnology using TFDEA & Lotka-Volterra models)

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Abstract

Virtually all mobile phones available today have embedded cameras and many of them have multi-megapixel resolutions. With the specifications and features of the smartphone cameras have improved, many users choose smartphones for casual photography and HD-movie clips leaving their compact point-and-shoot cameras and video camcorders at home. In this research paper we attempt to answer the question if and when camera phones would replace compact point and shoot cameras using (TFDEA) and Lotka-Volterra technology forecasting techniques.

Introduction

In today's age, technology has been improving and increasing in sophistication at an alarming rate. What could have been the top of the line and the most sophisticated advancement yesterday, could easily become obsolete and useless tomorrow. Since we all love to keep memories of our selves by taking videos and pictures of each other, this project will focus on the camera phone that has played a key role in helping one record memories.

Virtually all mobile phones available today have embedded cameras and many of them have multi-megapixel resolutions. With improved specifications and features, many users choose smartphones for casual photography and HD-movie clips leaving their compact point-and-shoot cameras and video camcorders at home. The smartphones enable easier operation and sharing of snapshots through apps and web-based services.

This new phenomenon makes people wonder whether the camera phones will ever replace the compact digital still cameras, if so, then when? That is the focus of this research and study.

Literature Review

Development of Digital Imaging Technology

The history behind digital imaging shows that the first imaging technology did not at all look the way digital cameras are now. They first became available in the 1970's for the consumer market thanks to Kodak Labs[1]

Kodak Lab, Rochester New York 1975 was the location at which the first digital photo was taken and recorded on a digital cassette tape. It was an assignment that Steven Sasson took on, who was an American electrical engineer, and the goal was to attempt to build an electronic camera that would utilize a charge coupled device. The prototype developed weighed 8 lbs and took 23 seconds to record a 100 x 100 pixel black and white image. After that Kodak went on to develop multiple solid state image sensors that would target both professional photographers as well as hobbyists.[1]

With Kodak's determination of maintaining itself as the lead innovator in the imaging industry it focused its efforts on image sensors. In 1986 they had a breakthrough were they managed to develop the first mega pixel sensor unit that had the ability to record 1.4 Megapixels. This was the start of a race that occurred in the industry. The technology behind the Camera began to develop faster and supporting technologies as the computer and printer industry have also managed to develop feature to aid in developing and editing images.[2]

The mobile phones have been developed rapidly over the past two decades, once an old and simple phone has became a smart phone with the processing power of a computer. With that evolution, another advancement occurred that was in the camera industry, where current smart phones have advanced digital imaging technologies . As the technology gets better in sophistication and advancement, there has been also an increase in competitiveness as well.

Compact Cameras

Compact cameras, also known as Point-and-shoot cameras or digital still cameras, have been around for a long time. Some of the big names that come to mind are Sony, Canon, Nikon, Kodakc, etc. In 1981, Sony developed and released a camera called Sony Mavica. This camera was an electronic still camera. It is known to be the first commercial electronic camera.[3] Sony Mavica was not considered a truly digital camera. In reality, it was a video camera that took video freeze frames.[3] This camera is known to have sparked the digital camera revolution era. The first truly digital cameras, however, were developed by Toshiba and Fujifilm in 1989.[3] Between 1994 and 1996, the first digital cameras made it to the consumer level market which worked with a computer connection to transfer pictures. Some of the manufacturers of the first digital camera models include Kodak, Casio, Sony cyber shot, and Apple Quick Take. This concludes that the era between 1981 and 1995 can be regarded as the "lift-off" stage of the digital camera's history.[3]

The basic digital camera structure contains an imaging device, imaging optics, image processer (DSP), LCD, buffer memory (DRAM), card/flash memory, electronic drive circuits and control mechanics. There are various imaging technologies that are available these days. There two major technologies that are being used are the Charge Coupled Device (CCD) and the Complementary Metal Oxide Semiconductor (CMOS). Both technologies have advantages and disadvantages. The other important core device in the digital camera is the lens optics. Lens optics are responsible for focusing a picture on the imaging device.

Camera Phones

Camera phones are very popular in today's market. The majority of people owning a mobile phone have cameras in their phone. Having a camera in the mobile is considered very important these days to consumers. It definitely plays a part when making a decision about buying a mobile phone. One major advantage for camera phones is the fact that a person can take a picture and share it almost instantly with other people using social networks. As far as the history for the camera phones, the two main suspects for the first camera phone are Samsung, which had a 0.35 megapixels camera, with the first camera phone released in the year 2000 in South Korea, and Sharp (0.11 megapixels) with the first camera phone (J-Phone) released in Japan.[4] Regardless of which one was the first camera phone, it seemed like the new millennium having a camera a main and a must component of a mobile phone. The first camera phone to hit the US market came from the Sanyo brand on Sprint network in 2002.[4] This phone offered a 0.3 megapixel camera. After that, the quality and megapixels of the camera phone has been on the rise and improving on every new phone that is coming into the market. Samsung later produced the first 5 megapixels camera phone.[4] Nokia, on the other hand, was the first company to prove to be a really popular camera phone for the international market which incorporates Carl Zeiss Optics. Nokia has led, and still leading the camera phone market with their latest phone the Lumia 1020 which incorporates a 41 megapixel camera. This phone also includes a true zooming experience that was never seen before on a camera phone. See Figure 2 for an example of a digital camera and a camera phone. [4]

FIGURE 1 A NIKON DIGITAL CAMERA VS. NOKIA N95 CAMERA PHONE

Camera phones have been on the rise since they entered the marked. The number of production for camera phones has increased significantly in the last decade. In 2004, 500 million mobile phones had been purchased, including 180 million camera phones. Generally because of the constraints of size and weight, the Imaging devices which are installed on camera phones tend to have fewer megapixels than those in digital cameras. This however might not be the case these days as the paper will talk more about how camera phones are competing strongly with the stand alone digital cameras. The results might just be surprising. [3]

Competition between compact cameras and smartphones

Sales of traditional digital cameras have declined due to the increasing use of smartphones for casual photography, which also enable easier manipulation and sharing of photos through the use of apps and web-based services. As smartphone cameras continue to improve, stand-alone compact cameras are starting to fight back with new functions like Wi-Fi and GPS.

Compact and bridge cameras are above all seeking to stand out with the kind of fundamental photography specs that most smartphones lack, such as optical zoom and other advanced features. For starters, zoom lenses are getting more and more powerful, reaching around 20x in pocket-sized compact cameras and up to 50x in bridge cameras.[5]

Sensor resolution is also drastically improved — most of the cameras on the market is y at 14 to 18 Megapixels these days. This surplus of pixels is more useful for cropping shots than for improving general image quality. Manufacturers are slowly abandoning the CCD technology favoring the backlit (BSI) CMOS sensors that provide much better performances in low light. The COMS sensors are faster too. Besides, the creative filters for fun effects (miniature, fish-eye, vivid, etc.) and sweep panorama functions are now a common feature of many compact cameras. [5]

Market share and Trends

The increasing popularity of smartphones is threatening the camera manufacturers and crushing demand for compact cameras by offering all-in-one phone, computer and camera with comparatively high quality pictures and Internet photo downloading. The global shipments of the compact cameras have been plummeting for the past several years due to the rapid rise of the smartphone as a camera of choice for casual photography. According to the Camera and Imaging Products Association (CIPA) report, production of compact cameras fell by almost half in the first half of 2013 compared to the same period last year, and total camera shipments fell by 42.7% in the same period. [6]

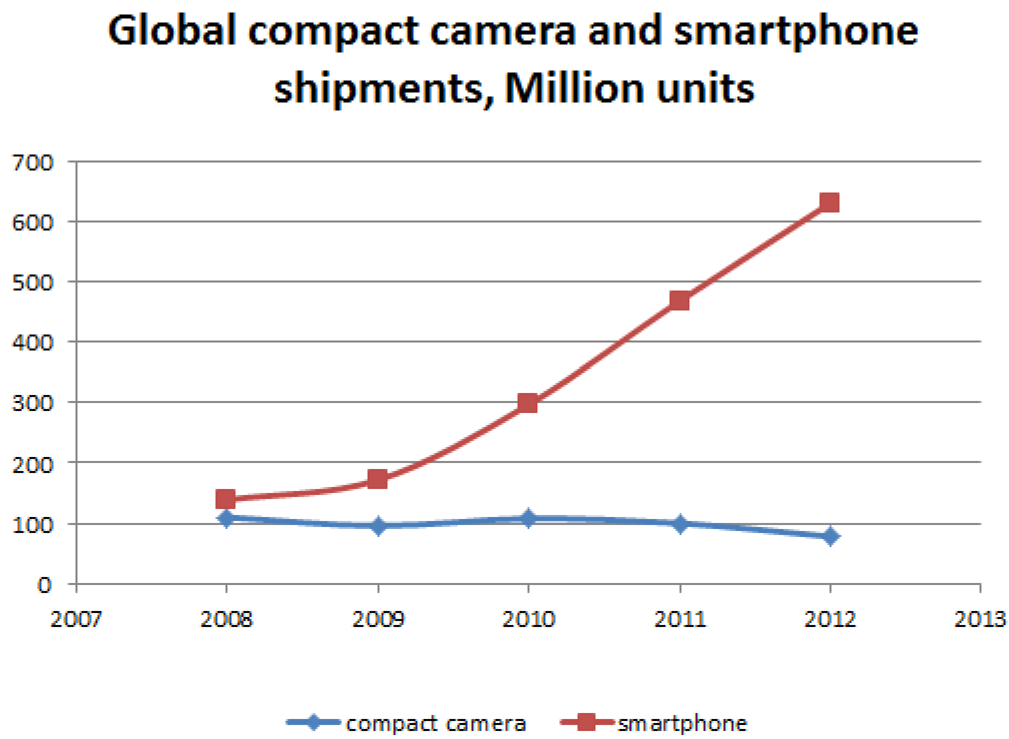

FIGURE 2 GLOBAL COMPACT CAMERA AND SMARTPHONE SHIPMENTS, MILLION UNITS[6]

According to Gartner, world's leading information technology research and advisory company, worldwide smartphone sales to end users reached 250.2 million units in the 3Q of 2013, up 45.8 percent from the same period of 2012. Asia-Pacific markets are leading the growth with 77.3% in the smartphone segments and with 11.9% in the mobile phone segment. The Americas and Western Europe markets show increase as well. Sales of smartphones reached their highest share to date accounting for 55% of overall mobile phone. [6]

	3Q of 2013 Units	Market Share %
Android	205,022.70	81.9
iOS	30,330.00	12.1
Microsoft	8,912.30	3.6
Blackberry	4,400.70	1.8
Others	1,566.00	0.6
Total	**250,231.70**	**100**

TABLE 1 GLOBAL SMARTPHONE SALES TO END USERS BY VENDORS IN 3Q OF 2013, THOUSANDS OF UNITS[7]

The most recent survey conducted by Info Trends has found that the embedded camera is the second most important feature in the purchase decision when choosing a phone. Nearly 86% of those who participated in the survey claimed that they own camera phones and 92% of them take photos on a regular basis.

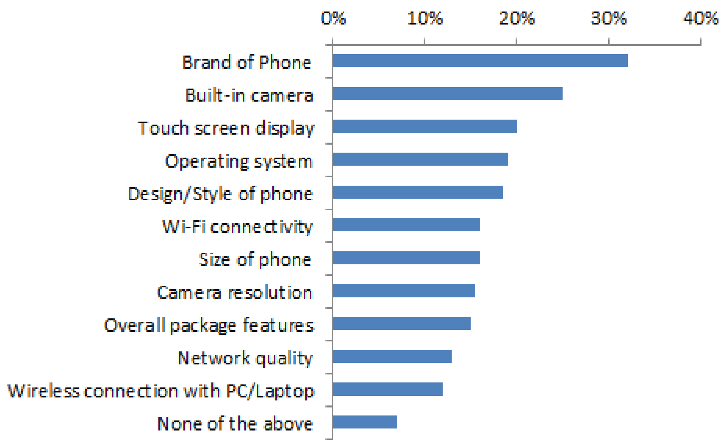

FIGURE 3 MOBILE PHONE DECISION – INFLUENTIAL FEATURES (TOP RESPONSES)[8]

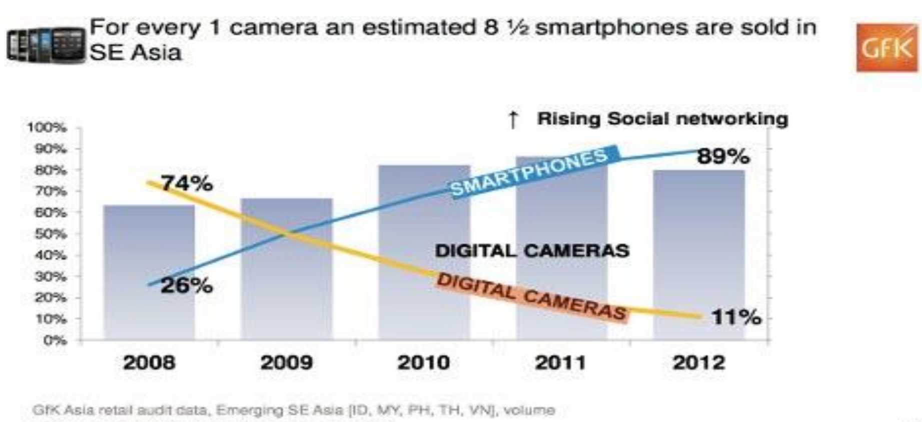

FIGURE 4 COMPACT DIGITAL STILL CAMERAS AND "GOOD ENOUGH CAMERA PHONE MARKET SHARE[9]

Research Framework

The technology behind camera phone's today has reached new heights like never before. It has established solid base ground and market share in the camera industry. It is eating away from the need of digital compact cameras, and it is showing that it can compete against these digital compact cameras. If we look at the scope of this paper, it is to determine whether or not camera phones will take over compact digital cameras. In this section of the paper we would be discussing the different research methods that we have conducted to be able to determine if camera phones will take over compact cameras or not.

To determine the solution we approached the problem utilizing two different methodologies. The first was to determine whether or not the technology behind camera phones are competent enough to take over the market from the digital compact cameras or not, and if not when will they be if ever. The modeled method we used to determine that is called TFDEA, which is technology forecasting using data envelop analysis.

Since the first model focused solely on the technology aspect of things, we determined that a second model should look at the consumer behavior and market trend towards the technology. That is to have an active understanding on how the technology behind the camera phone is affecting the market and market share of the digital compact camera and whether or not it would render the digital compact camera an obsolete technology or not. The model we have determine to be viable to study these competing technologies is the Lotka-Volterra model.

Methodology

In order to arrive to a conclusion as to whether the camera phone will replace the compact camera in the marketplace, as mentioned above we utilized two research approaches that we determined to be viable for this project.

TFDEA

For this research paper, we are going to assume that the current compact cameras satisfies the customers and they would prefer to only own a camera phone that is if the compact camera have similar specification or characteristics. TFDEA was utilized to determine when will the camera on the mobile phone reach customer desirability and satisfaction to replace the current compact camera technology.

Criteria Selection

In the market, there are many concerns for customers to decide whether to have either camera phone or compact camera. The decisions are based on hardware, ease to control, feature(Table 2), and image quality. In comparison, the compact camera has more advantage on optical zoom and the hardware that can produce better image quality. However, the ease of control and features on the camera phone are much better. [10] Comparing features illustrated below. From the research question, the decision of having only a smartphone or both camera phone and compact camera relies on the image quality of the camera phone. According to choosing camera, there are three major parts which affect the image quality.

Feature	Smartphone	Compact camera
GPS	X	X
Wi-Fi	X	X
Social network	X	X
Optical zoom		X
Digital zoom	X	X
Touch screen	X	X
LCD	Bigger	Smaller
External memory	X	X
Speed shutter	X	Better
Aperture	Fixed	Better
Flash	LED	Varity mode
Photo editing	X	X

TABLE 2 COMPACT CAMERA AND CAMERA PHONE FEATURE COMPARISON[11]

Lens optics system is a component which is responsible for sharpness of the picture , and speed shutter and aperture of camera. Speed shutter and aperture are mechanical features which allows light to pass through the image sensor. However, in the camera phone which have limited space, electrical techniques are used for eliminating that disadvantage.[12]

Image sensor is a device which converts light and color into digital signal. The better sensor could collect light in the darker condition, color depth, and higher s/n ratio with higher resolutions and low power consumption.[12], [13]

Image processor works on the digital signal to improve the picture quality in different ways such as boosting the contrast in order to raise contrast of the picture, using image processing techniques to reduce noise, white balance adjustment, color and tone correction, and sensor correction. This process includes encoding the picture format (Like RAW and JPEG).[12]

Even the quality of picture relies on the whole system. Image sensor is the heart of digital camera technology. [14] Thus, in the research, image sensor was chosen as a technology driver in order to forecast the different possibilities of the technology in the future.

Charge-coupled device (CCD) and complementary metal oxide semiconductor(CMOS) are two kinds of image sensors in the market. CCD is the first generation of image sensor which have been developed). Then, CMOS was launched with lower light sensitivity. Even though it has a lower light sensitivity, it has a higher performance scientific imager. CMOS has abilities to shrink the size down and lower the power consumption down with a lower cost. Moreover, with less complications on designing the sensor, this allows CMOS to have a variety of application to be used including increasing resolution. Another point is by increasing size of pixel is also to raise the light sensitivity even though make it better than the CCD technology.[15] After traditional or front-side illumination (FSI) CMOS was developed, in 2008 backside illumination (BSI) CMOS was invented to improve image quality and reduce the size of image sensors. BSI CMOS allowed more light to pass through the sensor and have smaller size of sensor. This fix disadvantages of CMOS and keep the advantages of it. [16] the summary of image sensor could see on the table 3.

Feature	CCD	FSI CMOS	BSI CMOS
1. Cost	Expensive	Cheap	Cheap
1. Light condition	Low light	Normal light	Low light
1. Pixel size	Large	Small-Large	Very small-Large
1. Power consumption	High	Low	Low
1. Complexity	High	Low	Low
1. SNR	Low	High	Medium-High
1. Frame rate	Slow	Fast	Fast

TABLE 3 IMAGE SENSOR COMPARISON

Image sensor application

	Average Zoom ability	Average image sensor size of camera
Smartphone camera	3x	1/3.2
Compact camera	10x	1/2.3
Large sensor compact camera	30x	1/1.5
APS-C DSLR	Interchangeable lens	35 mm
Full Frame DSLR	Interchangeable lens	32 mm

TABLE 4 IMAGE SENSOR AND APPLICATION[17]

Unit measured

1. Sensor size (measured in inches) is really important for camera phone market because when the image sensor gets smaller, it could fit in a small space. This could answers the space limit on camera phone.
2. Active power (mA) is the amount of power when taking photos or video recording functions are being used. This parameters is related to how much time that you could use the device.
3. Standby power (uA) is an amount of power when camera phone or compact camera are on, but the image sensor is not being used . This parameters is related to time that you could use the device.
4. Frame rate (frames per second) is the number of frames that image sensor could transfer the digital data to the next process(image processing) at the maximum resolution.
5. Signal to noise(S/N) ratio (dB) is the pixel signal divided pixel random noise. The higher is better.
6. Resolution is the number of pixels in the picture
7. Dynamic range (dB@8x gain) is the variety of color that the sensor could collect. The higher the value the better.
8. Luminance (mV/lux*sec) is the amount of light which the sensor could can collect per second. The higher the value the better.

Technology Forecasting using Data Envelopment Analysis

TFDEA is an analysis tool applied from Data Envelopment Analysis. DEA uses relative efficiency from each data set or decision-making unit. In the same direction of DEA, TFDEA use relative efficiency to measure or predict the product efficiency in the future. The first step is to identify the "state-of-art(SOA)" of the specific year or frontier year by comparing with the history which the SOA would be equal 1. The frontier will be compare with another product in difference year to identify rate of change(ROC) of the product, then use the rate of change to predict launched date of product. The last is to match launched year with predicted year and find the Mean Absolute Deviation(MAD). MAD is the number of error(years) which could have on the prediction.[18] In order to provide convenience for using TFDEA tools, the paper would use TFDEA add-in which was developed by R to use on Microsoft Excel.

Data gathering

The study is to identify the improvement of the image sensor. Data sets would be collected from datasheet from many manufacturers. However, according to the limitation of the available information , only one manufacturer, Omnivision, would be used. The data ranges from 2008 to 2013. The data sets are presented below.

From observation in 2008, the technique called "backside illumination" or BSI on the CMOS technology, allow to have better light sensitivity and smaller optical format. On the other hand, in the same size of optical format, it could have higher resolution. The sample and improvement of each criterion could see on the figures below.

No.	Part Number	Release Year	Y_number of Pixels	X_Optical Format (inch)	Y_Frame Rate (fps)	X_Active Power (mA)	X_Stand by Power (uA)	Y_Light Sensitivity (mV/lux*sec)	Y_Dynamic range (dB@8x gain)	Y_Max S/N ratio (dB)
1	OV10633	2011	921,600	0.33	30	532	480	3650	115.0	39.0
2	OV9724	2012	921,600	0.11	30	55	60	740	70.4	36.2
3	OV9740	2011	960,384	0.14	30	180	24	1300	70.0	36.0
4	OV9710	2008	1,024,000	0.25	30	110	50	3300	69.0	39.0
5	OV9715	2012	1,024,000	0.25	30	110	50	3300	69.0	39.0
6	OV9712	2013	1,024,000	0.25	30	110	50	3700	69.0	40.0
7	OV9726	2012	1,047,168	0.15	30	95	60	1300	70.0	36.0
8	OV9728	2013	1,047,168	0.15	30	60	20	1000	74.0	38.0
9	OV2655	2010	1,920,000	0.20	15	250	75	1030	66.0	37.0
10	OV2643	2011	1,968,288	0.25	15	150	30	1250	66.0	39.0

TABLE 5 DATA SETS IN TFDEA(ALL DATA SETS IN APPENDIX II) [19]

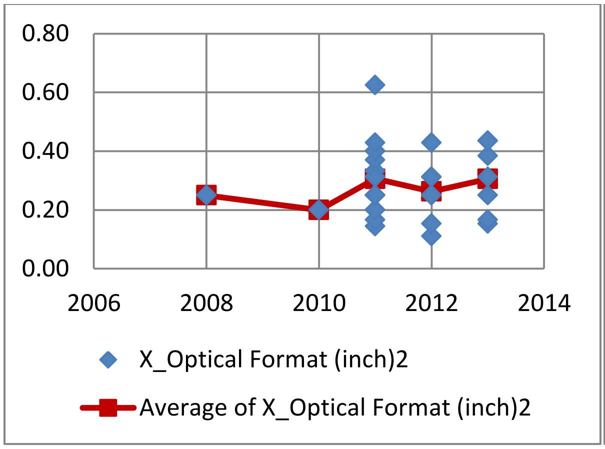

FIGURE 5 OPTICAL FORMAT

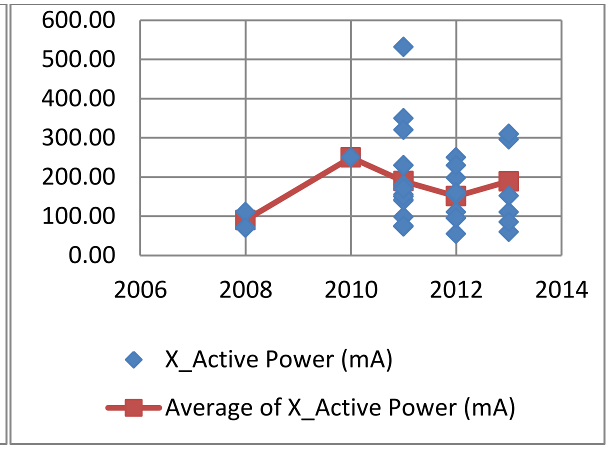

FIGURE 6 ACTIVE POWER

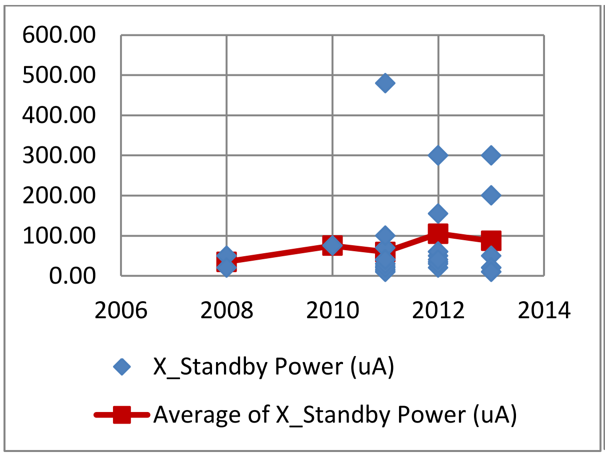

FIGURE 7 STANDBY POWER

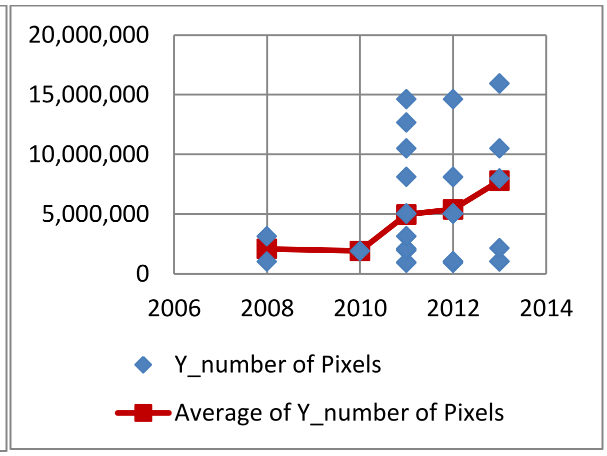

FIGURE 8 RESOLUTION

FIGURE 9 FRAME RATE

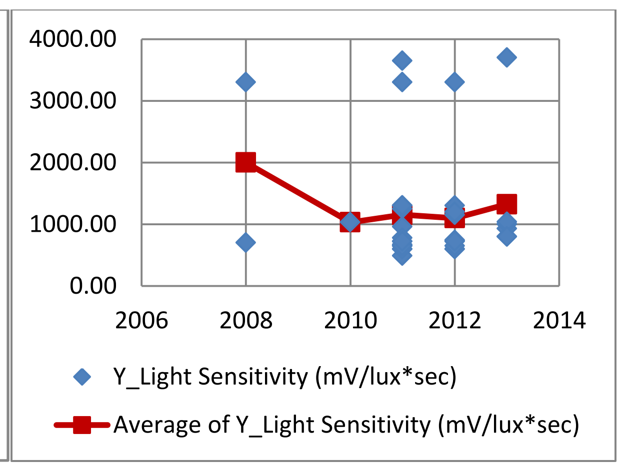

FIGURE 10 LIGHT SENSITIVITY

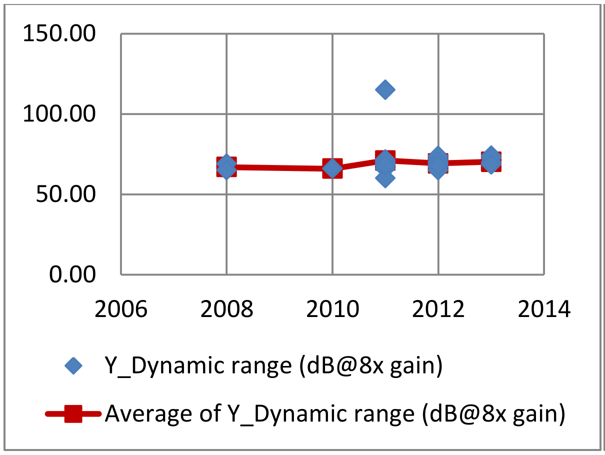

FIGURE 11 DYNAMIC RANGE

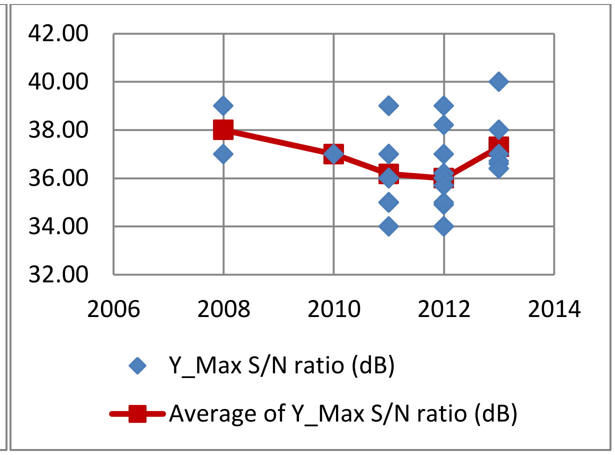

FIGURE 12 S/N RATIO

Model

In order to identify the quality of the image sensor in the future, which directly affect the picture quality, many criteria need to be considered. Some are available and some are not. After filtering all the criteria, the model for the image sensor technology forecasting can be structured like Figure 16. Sensor size, active power and standby power consumption would be on the structural variables side(Input) and resolution, frame rate, light sensitivity, dynamic range, and Signal to noise ratio(S/N ratio) on the functional variables side(output).

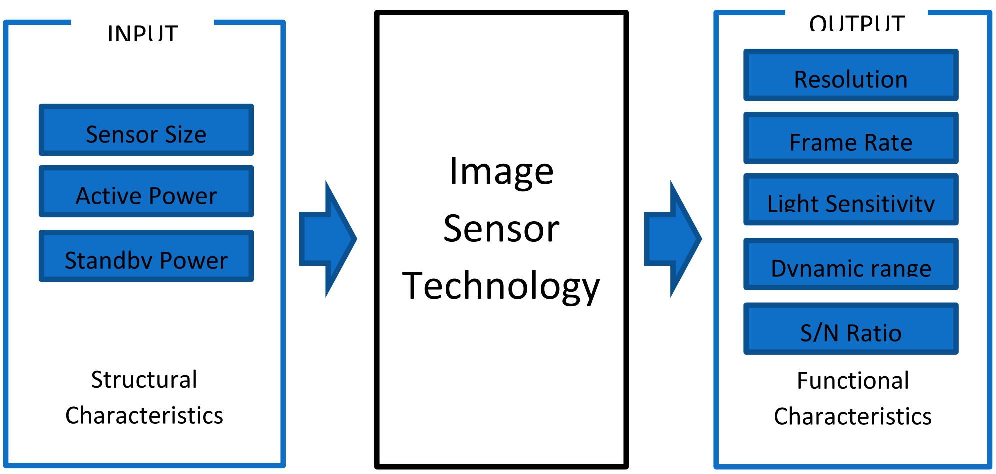

FIGURE 13 TFDEA MODEL

Result of TFDEA

According to the model, the setting of TFDEA model can be seen in figure 17. The frontier was set as Dynamic, and 2013 was the target frontier year in order to maximize the efficiency of DMU when comparing to others DMUs. The reason to set 2013 as the target frontier is that 2013 took all DMUs into consideration so as to find state of art(SOA) of each year. Constant return to scale(CRS) was set to imply that output and input efficiency would increase at the same value.

Moreover, it was set to output-oriented which means that this model was subject to increase the performance of output.

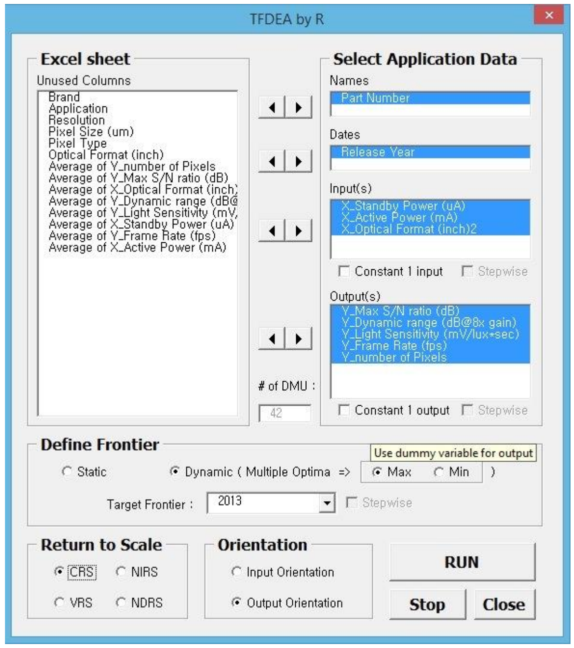

FIGURE 14 APPLICATION PROGRAMING INTERFACE (API) DIALOGUE BOX

The results from the TFDEA are illustrated in table 7. The Rate of change(ROC) is 1.0798 and Mean Absolute Deviation is 4 which means that the image sensor was improved by 7.98% each year with 0.56 years or 7 months error. From 37 data sets or DMUs, 21 image sensors were released to the market and still SOA in the 2013 frontier year. ROC was calculated from three samples. There is a product model released before the forecasted year and no product model is released after forecasted year. The forecasted released year of each DMU are illustrated below (Figure 18)

Results

Run by TFDEA add-in ver 2.2

Frontier Type	Orientation	2nd Goal	Return to Scale	Avg RoC	Frontier Year	MAD
Dynamic	OO	Max	CRS	1.079801	2013	0.566808
Input(s)	**Output(s)**	**SOA products at Release**	**SOA products on Frontier**	**RoC contributors**	**Release before forecast**	**Release after forecast**
3	5	21	17	3	1	0

TABLE 5 TFDEA RESULTS

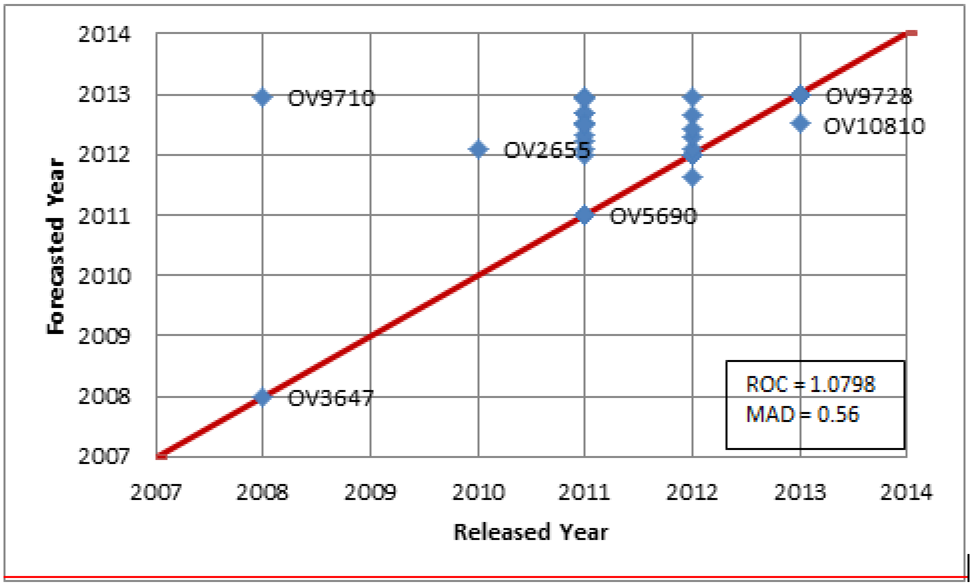

FIGURE 15 FORECASTING RESULT AT FRONTIER YEAR 2013

According to image sensor application table(Table 4), the image sensors at 1/3.2” inches was assumed that it is compatible for camera phone because the camera phone has limited space. Another are power consumption on Active and standby mode of image sensor are 13 mA and 40 uA since these are assumed that it is compatible with one-day-used without recharging. In the functional characteristics, the resolution was set at the highest specification for compact camera; resolution(16 MP), frame rate(30fps), light sensitivity(3700), dynamic range(74) ,and S/N ratio(40). As a result, these products could launch before or after the year 2022 by 7 months.

Name	Date	Efficiency_R	Efficiency_F	Effective Date	Rate of Change	Forecasted Date
OV9710	2008	1	1.06562995	2012.957565	1.012905	-
OV3647	2008	1	1	2008.000000	-	-
OV2655	2010	1	1.361348237	2012.104555	1.157862	-
OV10633	2011	1.046666667	1.121222126	2012.497410	-	-
OV9740	2011	1	1	2011.000000	-	-
OV2643	2011	1.293442266	1.356330078	2012.333414	-	-
OV2659	2011	1.185204514	1.26262059	2012.536676	-	-
OV2710	2011	1.335618449	1.458327692	2012.934295	-	-
OV2722	2011	1	1	2011.000000	-	-
OV2720	2011	1	1	2011.000000	-	-
OV3660	2011	1.042008753	1.064948727	2012.965114	-	-

TABLE 6 TFDEA RESULT FOR EACH DATA SET((ALL DATA SETS IN APPENDIX II)

Limitation of TFDEA in image sensor

There are many limitations on using just the image sensor technology to predict whether camera phone will replace compact camera. The first reason is that the launching date on the image sensor does not emphasize the time that the camera phone would be released. Another reason is that the image sensor samples' applications are too wide to specify which ones are image sensors for camera phone or compact camera. Moreover, information on camera phones' image sensor models are not available to see publicly. Even if the image sensor's specification itself has been limited to be accessed. The only company that allows to see the detail of its image sensors is Omnivision, while Samsung, Sony, and others do not present these information. Lastly, without using and forecasting all camera as a whole system in the analysis would lead to many misconceptions like not including the possibility of new technology on optics, image sensor , and image processing. Moreover, assuming technology target cannot illustrate actual use of the devices and desirability of customers or users. Thus, improving needs to be made by doing a survey to see the desirability and then taking the survey result to the experts or specialist to convert the result into technology target. Furthermore, technology dilemma need to be identify to see that customers are not willing to pay more when there is a specific technology. The reason is customers would always need the better technology.

Lotka-Volterra Model

The Lotka-Volterra model is a predator-prey competitive model. We will utilize it to determine the level of competitiveness in the market between the compact digital camera and the camera phone.

Background & History

As mentioned above the Lotka-Volterra model which is a predator-prey competitive model was developed in 1925 by Alfred Lotka and Vitto Volterra. The model was initially developed to serve as a mathematical formula to show the interaction between two species within an competitive environment through non-linear coupling[20].

Data Gathering

For the Lotka Volterra model the method at which we gathered data was by using two different approaches. The first approach focused on literature review, which was necessary to study as well as understand the different elements that contributed to the Lotka-Volterra model. The second approach was identifying the key elements that made up the model and gather the statistical data required to satisfy those components from various sources. The algorithm to the Lotka-Volterra model is provided below:

$$\frac{dN_1}{dt} = r_1 N_1 \frac{K_1 - (N_1 + \alpha_{12} N_2)}{K_1}$$

$$\frac{dN_2}{dt} = r_2 N_2 \frac{K_2 - (N_2 + \alpha_{21} N_1)}{K_2}$$

Lotka-Volterra Model	
a	Coefficient of Competition
K	Maximum Market Size
N	Current Market Share
r	Rate of Increase

TABLE 7 LOTKA-VOLTERRA VARIABLES

Since the Lotka-Volterra model required different elements, we will associate them with the information we gathered in the table below.

a = Was determined by calculating the change in rate of increase after the release of camera phones.
K = Is also known as the carrying capacity, which is the total amount of people who are able to purchase both technologies. That statistic was found through a process of elimination from different census bureaus. The population segment we searched for to determine the carrying capacity was middle to high class individuals with ages between 16 - 64 years of age.
N = Which is the current market share of a species in this case either the camera phone or the market share of the digital compact camera. This data was found through extensive literature review.
r = Rate of increase in our case is the rate of unit sales from one year to another.

Through various sources and extensive literature review, it was possible to gather the change in rate of increase as well as the rate of increase in our project from the unit sales of both the camera phone and the digital point and shoot camera.

Total Digital Point & Shoot Unit Sales	
Year	Total Unit Sales Per Year
2005	64766923
2006	78981429
2007	100367056
2008	119756808
2009	105863632
2010	108576298
2011	99830469
2012	77982104

TABLE 8 TOTAL DIGITAL POINT & SHOOT UNIT SALES[6]

Total Camera Phone Unit Sales	
Year	Total Unit Sales Per Year
2008	55000000
2009	125000000
2010	282500000
2011	485000000
2012	712000000

TABLE 9 TOTAL POINT & SHOOT DIGITAL CAMERA UNIT SALES BETWEEN YEARS 2005 – 2012

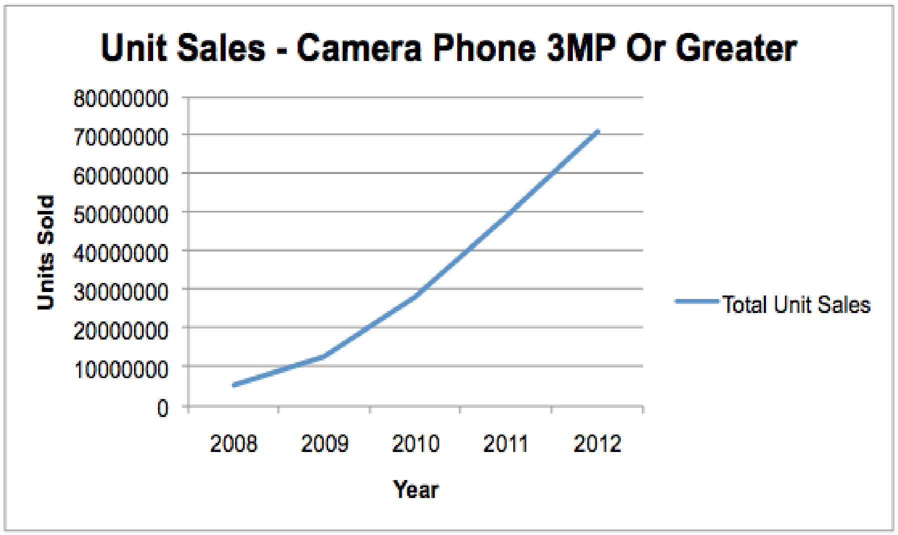

FIGURE 16 TOTAL CAMERA PHONE WITH 3MP OR HIGHER UNIT SALES BETWEEN 2008 - 2012[21]

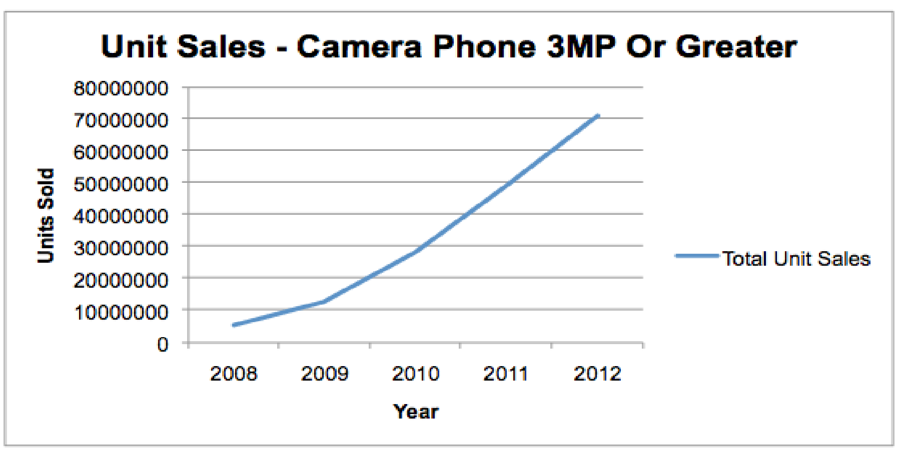

FIGURE 17 TOTAL CAMERA PHONE WITH 3MP OR HIGHER UNIT SALES BETWEEN 2008 - 2012[21]

Analysis of Lotka-Volterra Model

From the information provided regarding the model we have determined the values of our model from the data we have gathered. Since the model is a predator prey type of model, which studies the effects that one species has on another over a period of time. In this case it was to determine the effects one technology had on the other in the market place. It is to study the change in market share as well as unit sold as the camera phone interred the market.

To be able to study and compare these changes there where two different scenarios developed for this model. The first, which is the optimistic scenario that was calculated based on the industries high point that is the rate of increase that was the highest for the digital point and shoot camera. The second scenario, which is the pessimistic scenario determined the rate of increase that was the highest for the camera phone. These two different scenarios allowed us to accomplish a more comprehensive model.

Results

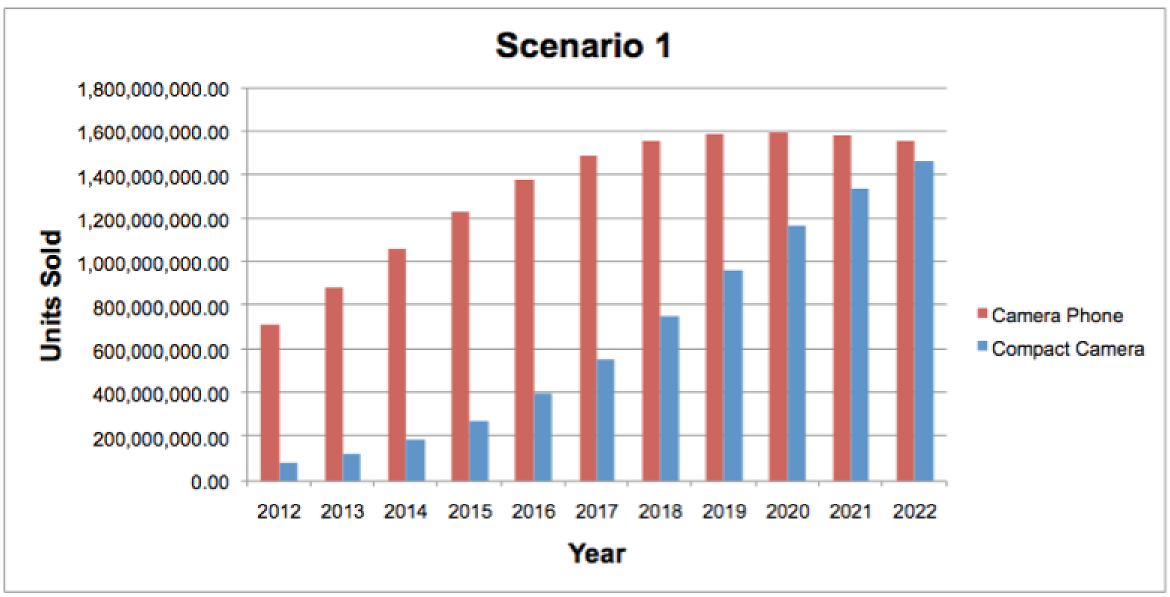

FIGURE 16 OPTIMISTIC COMPETITIVE SCENARIO

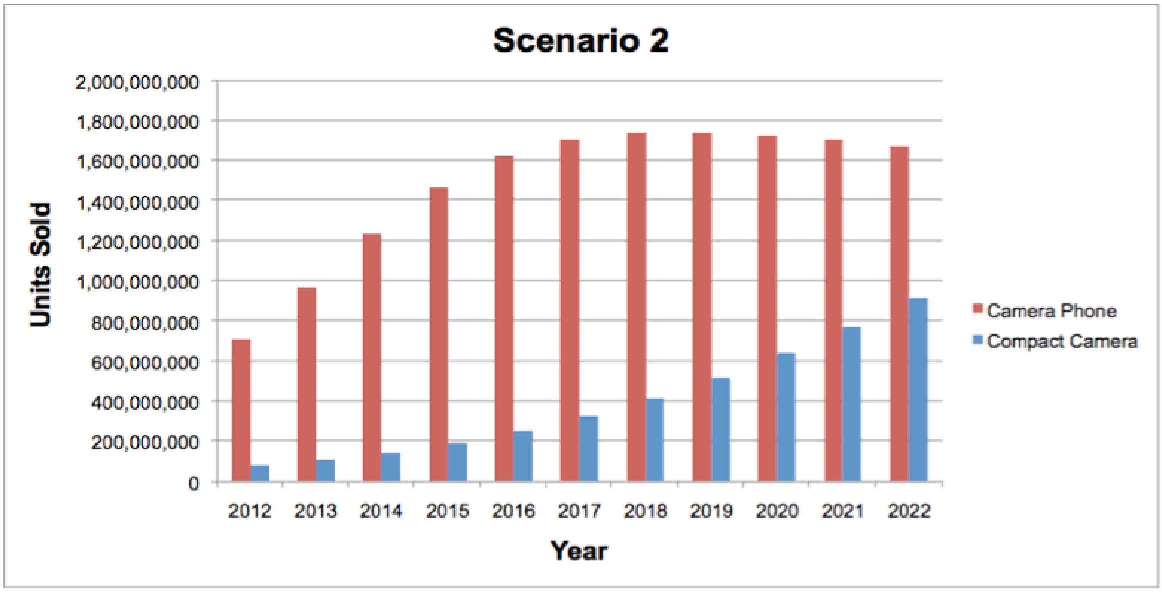

FIGURE 19 PESSIMISTIC COMPETITIVE SCENARIO

As the graphs provided above do not show the results that we were attempting to achieve. They both indicate that the camera phone is increasing in technology and market sale meaning that it was not affected at all by the market change although in the unit sales data we see that is not true. It was determine that this model was not viable for our project for multiple reasons that would be discussed in the next section.

Challenges & Limitation

From the results it was possible to observe that the model was contradicting the trend of the market. It was determine that due to the nature of the model, which focuses on the rate of increase, it is possible to assume that throughout the whole study both market share will increase.

The second limitation we have encountered with this model that is considered to be one of the key components that contributed towards the questionable results is that when the coefficient of competition is calculated it takes into account the affect or influence one element has on the other in a positive manner without taking into consideration the negative impact. Meaning if one has a positive increase the other is bound to have an increase.

The third limitation the could have affected this model is the different sources of information may have resulted in skewed data, although the trend might seem correct it is still not completely accurate.

The challenges that have been encountered in this model is that the calculation towards the coefficient of competition was difficult due to all the different approaches and possible methods of calculating it. Being able to determine the correct method to calculate the coefficient of competition is uncertain and requires further testing for this model and could also be considered a limitation that could have affected our overall results.

Future Research

From our conducted research we have been able to determine a certain trend of the market as well as the technology capabilities of the different camera types. Although it did not result in a conclusive result it was possible to identify the trends in both the technology sector as well as the market sector. The future research that was determined would solidify our study and cover the limitation that where found in the different models as well as determining a better time frame as to when one technology might take over the other are listed at follows:

1. Survey: Establishing a survey that would cover the average consumers state of satisfaction when it comes to the need for a point and shoot camera while already having a camera phone would allow for further statistical analysis to the direction of the market. Also another survey is to be done by technical and photography professionals that would evaluate the technologies and the rate of increase in the technological development field would allow for an experts opinion on the technology.
2. Competitive Market Model: From the study it was determined that the Lotka-Volettera model did not provide with a valuable response, but it is still important to study the market segment because it is a driving factor for all companies. A Market competition model or competitive market model would allow for a more comprehensive market evaluation of the different products.
3. Socioeconomics: Analyzing the different economic factors of the consumer market and the affect that they might have on both products would be beneficial. An example is in the data gathered it was possible to see a decrease in the amount of point and shoot cameras at the year of 2008 while the sales of the camera phone started off and increased ever since. Was that due to the 2008 economical crash or did the consumer shift their focus towards purchasing other items.
4. Bibliometric & Patent Analysis: Studying the patent and bibliometric statistical data would allow for further understanding towards the rate of technological increase in the camera industry. It would ultimately help support our TFDEA data as well as the results developed from the model.
5. System Dynamics: Although this might be the last research method mentioned it is by far one of the most important. That is because system dynamics models the dynamics of a complex systems. The benefit is that it would be possible to add all factors that may affect the outcome results to the model. It analyzes the whole system allowing for a more accurate solution.

Summary

The research paper covered multiple key points of which helped contribute to the evaluation of our research question of whether the camera phone will overtake the compact camera or not. As a result of the literature review and the different evaluations of the market that where found. The trend of the market and public purchasing power suggests that the convenience of the camera phone will eventually take over the digital point and shoot camera.

The forecasting tools that we have utilized to support that hypothesis where the TFDEA and Lotka-Volttera model. It was determined by the TFDEA model that the image sensing technology in the camera phone would reach that of the compact camera within the next 10 years. As for the Lotka-Volttera model it showed that the digital point and shoot camera is catching up in the market segment and will eventually surpass the camera phones market sales although the market shows otherwise. That resulted in deeming the Lotka-Volttera model as an inadequate study for the market segment because of the nature and limitations of the model.

Although our the research paper could not identify a solid definitive answer to our question. It is possible to observe that the trends and data gathered as well as the simulations performed suggested that the camera phone will eventually render the point and shoot camera as an obsolete technology. Our research could not indicate at what time period that might occur but with future research and the employment of different models, it might be possible to determine when that might happen.

Conclusions

In conclusion the research paper studied two different segments to identify a viable solution as to whether the camera phone will take over the digital point and shoot camera or not. The first segment was the technological segment, which was studied utilizing the TFDEA model. As for the second segment, it was focused on the market and consumer trends and utilized a competitive Lotka-Volttera model. Utilizing those two models contributed to different answers but with the extensive literature review as well as the possible implication.

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Appendix

No.	Part Number	Release Year	Y_number of Pixels	X_Optical Format (inch)	Y_Frame Rate (fps)	X_Active Power (mA)	X_Stand by Power (uA)	Y_Light Sensitivity (mV/lux*sec)	Y_Dynamic range (dB@8x gain)	Y_Max S/N ratio (dB)
1	OV10633	2011	921,600	0.33	30	532	480	3650	115.0	39.0
2	OV9724	2012	921,600	0.11	30	55	60	740	70.4	36.2
3	OV9740	2011	960,384	0.14	30	180	24	1300	70.0	36.0
4	OV9710	2008	1,024,000	0.25	30	110	50	3300	69.0	39.0
5	OV9715	2012	1,024,000	0.25	30	110	50	3300	69.0	39.0
6	OV9712	2013	1,024,000	0.25	30	110	50	3700	69.0	40.0
7	OV9726	2012	1,047,168	0.15	30	95	60	1300	70.0	36.0
8	OV9728	2013	1,047,168	0.15	30	60	20	1000	74.0	38.0
9	OV2655	2010	1,920,000	0.20	15	250	75	1030	66.0	37.0
10	OV2643	2011	1,968,288	0.25	15	150	30	1250	66.0	39.0
11	OV2659	2011	1,977,984	0.20	15	142	30	960	66.0	36.0
12	OV2710	2011	2,073,600	0.37	30	350	70	3300	69.0	39.0
13	OV2722	2011	2,109,744	0.17	30	74	15	650	68.0	35.0
14	OV2720	2011	2,109,744	0.63	30	74	15	650	68.0	35.0
15	OV2724	2013	2,139,392	0.17	30	85	20	930	70.0	37.0
16	OV3647	2008	3,145,728	0.25	15	70	20	700	65.0	37.0
17	OV3660	2011	3,145,728	0.20	15	98	20	670	70.0	34.0
18	OV3640	2011	3,145,728	0.25	15	75	10	490	60.0	36.0
19	OV5690	2011	5,038,848	0.25	30	155	10	780	71.6	36.0
20	OV5640	2011	5,038,848	0.25	15	140	20	600	68.0	36.0
21	OV5653	2011	5,038,848	0.31	15	150	40	1300	69.0	37.0
22	OV5650	2011	5,038,848	0.31	15	150	40	1300	69.0	37.0
23	OV5648	2012	5,038,848	0.25	15	198	35	600	67.0	34.0
24	OV5647	2012	5,038,848	0.25	15	96	20	600	67.0	34.0
25	OV5680	2012	5,038,848	0.31	30	250	155	1150	72.0	38.2
26	OV5656	2012	5,038,848	0.31	30	155	300	1200	73.7	37.0
27	OV8835	2013	7,990,272	0.31	30	152	300	1000	68.7	36.6
28	OV8850	2012	8,081,920	0.25	24	160	300	650	65.0	34.9
29	OV8820	2011	8,108,160	0.31	24	170	30	600	68.0	35.0
30	OV8825	2012	8,108,160	0.31	24	160	30	725	70.5	35.7
31	OV10810	2011	10,506,240	0.40	30	320	100	720	71.0	35.0
32	OV10820	2013	10,506,240	0.38	30	296	200	1039	72.5	36.7
33	OV12825	2011	12,672,000	0.40	15	230	40	650	71.0	35.0
34	OV14810	2011	14,625,792	0.43	15	230	40	720	68.0	35.0
35	OV14825	2012	14,625,792	0.43	15	230	40	720	68.0	35.0
36	OV16820	2013	15,925,248	0.43	30	310	10	800	68.6	36.4
37	OV16825	2013	15,929,856	0.43	30	310	10	800	68.6	36.4

TABLE 10 DATA SETS IN TFDEA [20]

Name	Date	Efficiency_R	Efficiency_F	Effective Date	Rate of Change	Forecasted Date
OV9710	2008	1	1.06562995	2012.957565	1.012905	-
OV3647	2008	1	1	2008.000000	-	-
OV2655	2010	1	1.361348237	2012.104555	1.157862	-
OV10633	2011	1.046666667	1.121222126	2012.497410	-	-
OV9740	2011	1	1	2011.000000	-	-
OV2643	2011	1.293442266	1.356330078	2012.333414	-	-
OV2659	2011	1.185204514	1.26262059	2012.536676	-	-
OV2710	2011	1.335618449	1.458327692	2012.934295	-	-
OV2722	2011	1	1	2011.000000	-	-
OV2720	2011	1	1	2011.000000	-	-
OV3660	2011	1.042008753	1.064948727	2012.965114	-	-
OV3640	2011	1	1	2011.000000	-	-
OV5690	2011	1	1	2011.000000	-	-
OV5640	2011	1.061873032	1.121473308	2012.962951	-	-
OV5653	2011	1.216830307	1.27165227	2012.674948	-	-
OV5650	2011	1.216830307	1.27165227	2012.674948	-	-
OV8820	2011	1.052349455	1.091056213	2012.103079	-	-
OV10810	2011	1.050836611	1.256626913	2012.529690	-	-
OV12825	2011	1.01674029	1.045770407	2012.222617	-	-
OV14810	2011	1	1	2012.000000	-	-
OV9724	2012	1	1	2012.000000	-	-
OV9715	2012	1	1.065629946	2012.957565	1.068636	-
OV9726	2012	1.067097674	1.096594796	2012.089788	-	-
OV5648	2012	1.142080069	1.201050968	2012.653041	-	-
OV5647	2012	1	1	2012.000000	-	-
OV5680	2012	1.357044841	1.429674046	2012.277775	-	-
OV5656	2012	1.277974727	1.305494947	2012.413903	-	-
OV8850	2012	1	1	2012.000000	-	-
OV8825	2012	1.052513122	1.057775629	2011.614562	-	-
OV14825	2012	1	1	2012.000000	-	-
OV9712	2013	1	1	2013.000000	-	-
OV9728	2013	1	1	2013.000000	-	-
OV2724	2013	1	1	2013.000000	-	-
OV8835	2013	1	1	2013.000000	-	-
OV10820	2013	1.164284283	1.164284283	2012.514164	-	-
OV16820	2013	1	1	2013.000000	-	-
OV16825	2013	1	1	2013.000000	-	-
forecsast	2022	1	0.459362528	2012.434618	-	2022.566808

TABLE 11 TFDEA RESULT FOR EACH DATA SET((ALL DATA SETS IN APPENDIX II)