Mobile device trends from 1989 to 2013

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***Abstract*—This paper targets the data provided to us for the final group assessment of Visual Analytics unit in lieu of the postgraduate course provided by the University of Sydney. This paper analyses the data using visualizations created from the data provided using Tableau, Excel, Python, etc. to analyze and realize the trends of the mobile devices from the year 1989 to 2013.**

Keywords—Visual analytics, trends, prediction, mobile devices, tableau, python, visualizations, interactive visualizations.

I. INTRODUCTION

Technology has been something which has been increasing the survival of humankind since the start. Today we use technology not only as a means of survival but also as a means of being productive, entertainment, and much more. The assignment focuses on one such product of technology: Mobile devices. Since the creation of the first mobile device in 1973 [1] the race to commercialize the mobile devices began. Today, almost 91% of the entire population on earth has mobile devices [2]. The assignment provides us data with the specifications of these mobile devices for the period 1989 to 2013. Our task is to visually analyse this data and come up with the different mobile types based on these specifications, the trends associated with it through the years and consequently predicting the newly emerging type of mobile devices. Following is a brief description of the data provided to us.

II. DATA

A. Introduction

The data used for this assignment is one which has been provided from the faculty. The data contains information on the different mobile devices introduced in the period from 1989 to 2013 along with their features such as RAM, Storage, CPU Clock, etc. The data set is in the form of a workbook containing 3 different sheets. These sheets are:

- Company ID
- Model-Company
- Normalized Product Data

These sheets were used to produce visualizations through multiple platforms such as Python, Tableau, and Microsoft Excel. For tableau, the data was connected to each other using the following diagram:

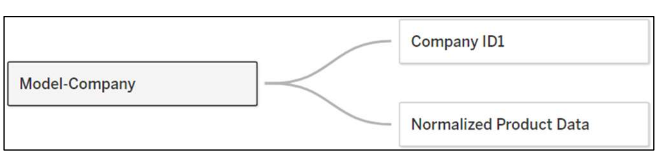

Fig. 1. Schematic diagram for connecting the data in Tableau.

B. Data types involved

The dataset has been created from the union of 3 distinct datasets. The attributes, data type and description of the data is as follows:

Table 1. About the data

About the Data		
Attribute	***Data Type***	***Description***
Model	Qualitative	Model name of the mobile device
Release Date	Date	The release date of the model
Release Year	Date	The release year of the model
Model ID	Qualitative	The ID given to each model
RAM Capacity (Mb)	Ratio	The memory capacity of the mobile device
Storage (Mb)	Ratio	The storage capacity of the device
CPU Clock (MHz)	Ratio	The processing speed of the device
Display diagonal (in)	Ratio	The diagonal length of the screen
Display width (px)	Ratio	The width of the screen
Display length (px)	Ratio	The length of the screen
Width (mm)	Ratio	The width of the device
Length (mm)	Ratio	The length of the device
Depth (mm)	Ratio	The thickness of the device
Volume (cubic mm)	Ratio	The volume of the device
Mass (g)	Ratio	The mass of the device
Pixel density (per inch)	Ratio	The number of pixels per unit area
Company ID	Qualitative	The ID given to each Company
Company	Qualitative	The code given to each company
Company real	Qualitative	The actual name of the company

C. Data Described

The data we used were primarily the Release year, Model ID, Company real, RAM capacity, Storage, CPU Clock, Display diagonal, Mass, and Pixel Density. Using python, we have derived some basic statistics for each of the attribute being used:

	RAM Capacity (Mb)	Storage (Mb)	CPU Clock (MHz)	Display Diagonal (in)	Mass (grams)	Pixel Density (per inch)
count	3162.000000	3162.000000	3162.000000	3162.000000	3162.000000	3162.000000
mean	0.173344	0.072830	0.324088	0.170078	0.036614	0.333562
std	0.208682	0.165589	0.210708	0.136092	0.054600	0.159551
min	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25%	0.031220	0.002096	0.183002	0.079137	0.013793	0.212519
50%	0.062471	0.004194	0.263664	0.129496	0.018966	0.288743
75%	0.249977	0.062080	0.499772	0.187050	0.031897	0.452802
max	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000

Fig. 2. Statistics for the used attributes using Python.

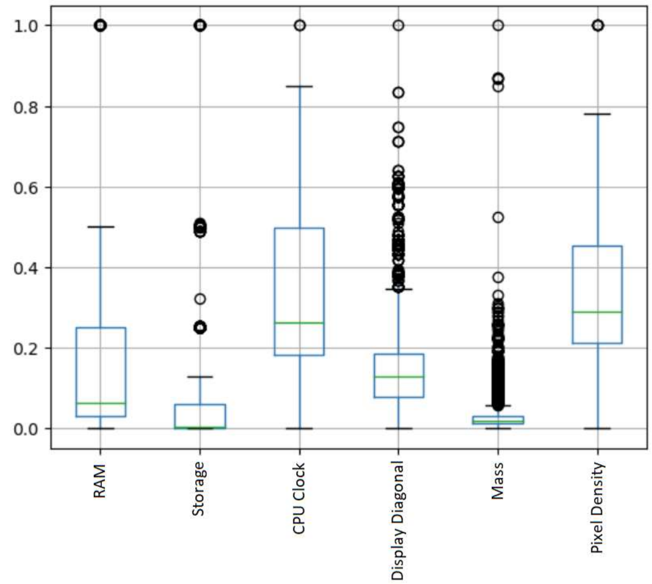

Fig. 3. Boxplots for each of the used attributes using Python.

The box plot was used for the Figure 3 as it could represent all the data points very easily in an easy-to-understand format. Initially we used a bar graph for each of the attribute which was later changed into the box plot. The reason for change was to compile all the relevant information from multiple visualizations in a single, easy to read graphic. The y axis represented the value for each attribute and the x axis represented the attributes. Through this arrangement we were able to easily compare between different attributes understand more about each attribute through the years.

III. Exploring the Data

A. General analysis of the data

Through analysing the data, we now know the major statistics for each of the attributes. For further data exploration, we try to find out more about the qualitative data; that is the companies, the models, etc. Through visual analysis of the data, we determined the following:

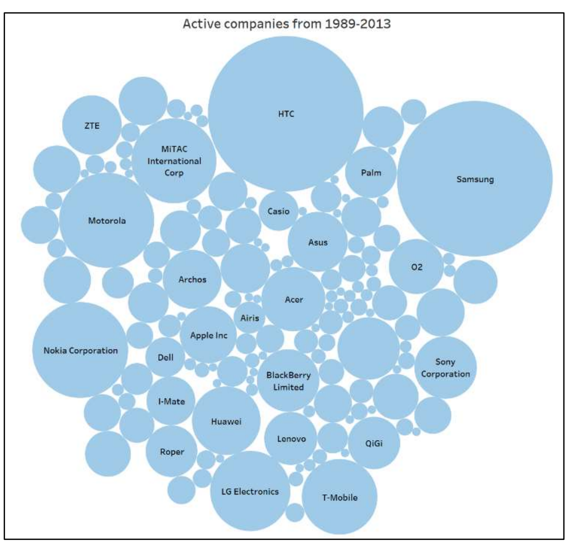

Fig. 4. Bubble chart for the active companies for the period 1989 to 2013.

Figure 4 used a bubble chart as we wanted to represent the number of active companies in the market from 1989 to 2013. Along with which we used the size of each bubble to demonstrate the number of unique models which each company released. Through this visualization we understand the degree of activeness of each company, how many models they released in the span of 25 years, etc.

Through Figure 4 we understand the overview of the different companies and a rough estimate of the relative number of mobile devices released by the companies. Samsung, HTC, Motorola, Nokia, MITAC International Corp, LG Electronics, etc. are conclusively the most active companies in this period considering the size of the bubble represents the number of models released by each of the companies. The top 10 active companies are further clearly represented in Figure 5.

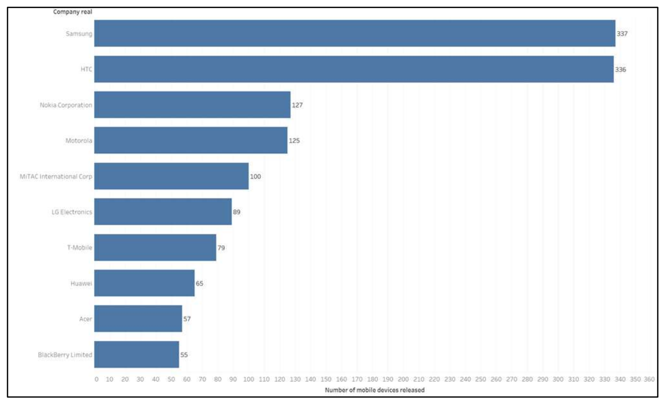

Fig. 5. The top 10 active companies.

For figure 5, we used a horizontal bar graph to display the top 10 active companies in the market for the 25 years. Initially we used a pie chart to represent the information, but the pie chart seemed cluttered and was a bit difficult to read. This caused us to change the visualization to the horizontal bar graph which was able to display the information in a much clearer and concise way.

This led us to consider the rate at which companies released new models.

Company real									
CipherLab	4.333	Socket Mobile, Inc	2.000	Toshiba Corpora..	1.435	Sprint Corporati..	1.056	MENQ Internati..	1.000
Samsung	4.266	Tapwave	2.000	Foxconn Technol..	1.429	AboCom Systems	1.000	Mobile TeleSyst..	1.000
Opticon Inc	4.000	Zopo Mobile	2.000	Meizu Technolog..	1.429	AIRO WIRELESS, ..	1.000	Olympus Corpor..	1.000
Yukyung Technol..	4.000	Hewlett-Packard	1.929	NTT DOCOMO, Inc	1.409	Anydata Corpora..	1.000	Optima Technolo..	1.000
HTC	3.200	Nokia Corporati..	1.924	Airis	1.400	Arima Communic..	1.000	Oregon Scientific	1.000
Cowon Systems, ..	3.000	Huawei	1.912	DreimGO	1.400	Axia	1.000	Pantech	1.000
Fourier Systems	3.000	Blaupunkt	1.833	Navigon GmbH	1.400	Babiken	1.000	Philips	1.000
Archos	2.882	Dell	1.833	RoverComputers	1.391	BBK Electronics ..	1.000	Real Aegis Techn..	1.000
Yarvik Nextec	2.857	Wayteq Technol..	1.833	Asus	1.389	Bsquare Corpora..	1.000	Rogers Wireless	1.000
Apple Inc	2.813	Bluebird Soft Inc	1.800	I-Mate	1.375	Camangi	1.000	Sendo	1.000
Casio	2.750	Alcatel-Lucent	1.789	Inventec Corpor..	1.375	Chi Mei Commun..	1.000	SiemensæAG	1.000
Sony Corporation	2.700	Google	1.667	Amazon	1.333	Cincinnati Bell	1.000	Silicon-i	1.000
Navon MIZU	2.500	Kinpo Electronic..	1.667	Shenzhen Ainol ..	1.333	Clearview Techn..	1.000	Spice Digital	1.000
Roper Technolog..	2.467	Acer	1.629	Tibo	1.333	Commtiva	1.000	Sunno	1.000
MiTAC Internati..	2.273	Kyocera Corpora..	1.615	O2	1.313	Coxion	1.000	Tatung Company	1.000
LG Electronics	2.225	Barnes & Noble	1.600	NDrive	1.286	Creative Technol..	1.000	Telecom Italia	1.000
Motorola	2.193	Amoi Technolog..	1.571	TechFaith Wirele..	1.286	Data Evolution C..	1.000	ThinkNavi	1.000
ZTE	2.130	Mobile Compia	1.545	E-TEN Informati..	1.278	DataWind	1.000	TORQ	1.000
Zebra Technolog..	2.067	T-Mobile	1.519	NEC Corporation..	1.273	E-noa	1.000	UMI DIGI	1.000
Lenovo	2.053	AT&T	1.500	Palm	1.267	enTourage	1.000	Union Rich Devel..	1.000
Argox	2.000	Coolpad Group Li..	1.500	SoftBank	1.267	Garmin Ltd	1.000	United Internet	1.000
FirstOne Technol..	2.000	EKEN Electronic	1.500	Trimble Navigati..	1.250	HannStar Displa..	1.000	Verzio Mobile	1.000
Handspring Inc	2.000	Micromax Infor..	1.500	Unitech Electron..	1.250	Hitachi, Ltd	1.000	Wistron Corpora..	1.000
Hongfutai E-Tec..	2.000	Microsoft	1.500	Xiaomi Inc	1.250	Hunan Suning Pi..	1.000	Zenum	1.000
iconX	2.000	Simvalley Mobile	1.500	Sharp Corporati..	1.214	Inq Mobile	1.000	Ziss HongKong	1.000
Notion Ink	2.000	ViewSonic	1.500	Vodafone	1.208	Into Blu	1.000		
Onkyo Corporati..	2.000	BlackBerry Limit..	1.486	Gigabyte Techno..	1.167	Join Technology	1.000		
QiGi	2.000	Orange UK	1.450	BenQ	1.143	LavaæInternatio..	1.000		
RoyalTek	2.000	Intermec	1.444	Verizon Commun..	1.091	MAG Digital	1.000		
Sierra Wireless	2.000	Fujitsu Ltd	1.438	Panasonic	1.083	Medical Phone Ltd	1.000		

Fig. 6. The number of new devices released per year as Rate of Release.

We used the highlight tables to determine the release rate. We created a calculated field called "Rate of Release" and determined the number of models being released per year by the companies. This was then displayed using the highlight table. The darker the rate of release, the higher it is and vice versa. This arrangement made it easier for the viewers to make out which company had more releases compared to the others based on colour rather than the number associated with it.

Through figure 6 we can see a faint relation between the top 10 companies and the number of devices released each year. The top 10 have a higher rate of release as compared to the others. This can make us infer that these companies have a good research and development team considering their ability to release a new model with new specifications every year.

B. Characteristic trend release based on the attributes

The mobile devices are characterised by their attributes such as the RAM, Storage, CPU clock, etc. The major attributes used for this analysis are RAM, Storage, CPU Clock, Display size (diagonal), Mass and Pixel Density. These attributes have been changing through the years, this can be verified using figure 7.

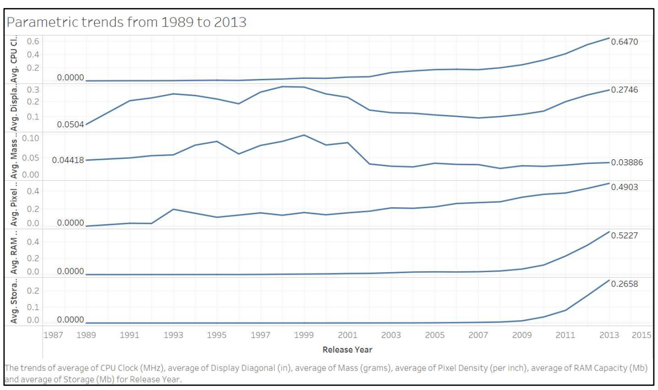

Fig. 7. Trends of each parameter through the years.

Figure 7 displayed the trends for each of the considered attributes. The line graph was the best approach to display the trend as it could show the minute changes across time for the attributes. We combine each of the attributes and used their average to create the graph and display them together so that it is easier to understand the trends and perhaps we could create some links between the attributes.

C. Trends based on the RAM

There are different types of RAMs such as SRAM, DRAM, SDRAM, SGRAM and HBM. SRAM is also known as Static Random Access Memory and the first SRAM was introduced in 1963 [3]. Around 1987 the SRAM which had been introduced for the first time had a total capacity of 1Mbit which continuously kept progressing and by the end of 1995 [4], the last year the SRAM was used, Hyundai manufactured a SRAM with a capacity of 256Mbit [5]. The DRAM, also known as the Dynamic Random Access Memory, was also introduced with a capacity of 1bit in 1965 [6]. Around 1988 IBM manufactured and introduced a 512Kbit capacity DRAM which kept developing until the final DRAM had a capacity of 4Gbit released by Samsung in 2001 [7]. The Synchronous Dynamic Random Access Memory (SDRAM) was by far the most advanced when it was introduced in 1992 with a capacity of 16Mbit by Samsung [8]. This capacity kept increasing every year with the last introduction in 2018 which had the capacity of 128 Gbit [9].

On this note, one can clearly see the evolution of mobile devices with the continuous development of RAM. 1989 was the first year when a non-brick mobile device, a flip-phone, was launched. This coincides with the introductory stages of the SRAM with the capacity of 1Mbit. Continuing this, we receive the Personal Digital Assistant (PDA), also known as the handheld PC. This was first introduced in 1992 where the RAM capacity using SRAM was reaching 1Mbit. The first tablet, a PDA, was introduced by Apple. Furthermore, the mobile devices took a turn in 2007 with the introduction of the first iPhone. An entirely touchscreen mobile device, a smartphone. This smartphone completely changed the mobile device industry with its RAM being at 4Gb and 8Gb respectively. We can clearly see through this, that the development of RAM and the development of the mobile devices coincides. This leads us to determine the types of mobile devices based on the RAM. These types are broadly classified as Flip-phones, PDAs, and Smart phones.

Flip-phones are those which were existent in the early years of the development of RAM. These phones were immensely popular in contrast to the brick phones which were introduced earlier and weighed around 400g. The RAM for such phones were generally very less as compared to the smartphones which had their RAM in GB. The PDAs were introduced in 1992 which had a RAM of 128kb and 512kb respectively. This coincides with the SRAMs used with the max capacity of 1Mbit.

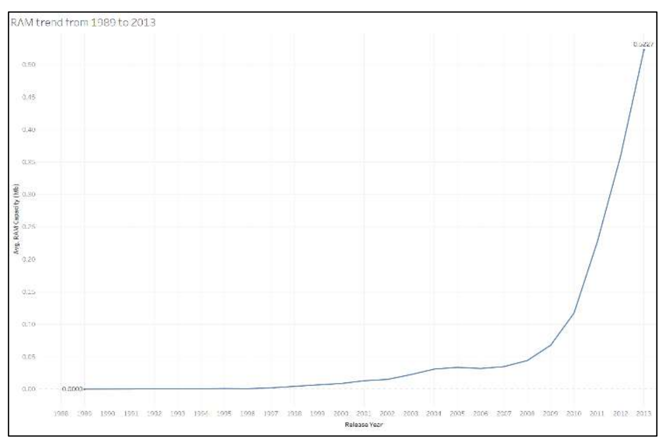

Fig. 8. RAM trends from 1989 to 2013.

As discussed earlier, a line graph is the best to visualize trends as it can depict the minor changes over time. Figure 8 was created using the same reasoning. The x-axis represented the release year whereas the y-axis represented the average RAM for all the devices released in that particular year.

Through this visualization we were clearly able to understand the trends of RAM through the year.

IV. Types of Mobile Devices

There are many different types of mobile devices which were invented and used from 1989 to 2013. A few such mobile devices are Flip-phones, tablets, PDAs, laptops, smartphones, etc. We can note that, the mobile devices have had an upgrade in RAM every successive year and has kept increasing. Using this we theorized that the RAM can be used for differentiating the different types of devices. Knowing that the mobile devices can be differentiated on a much deeper level using CPU, RAM, Storage, the physical dimensions, etc. we differentiated the mobile devices on a broad category of flip-phones, tablets and smartphones based on the RAM. Figure 9 shows the statistics of RAM through the years in the form of a boxplot. The reason we use the boxplot is so that we can capture and visualise the statistical measure for every datapoint, that is the model. This way we can give statistical information about the graph such as the median, quartiles, outliers, etc. at a glance.

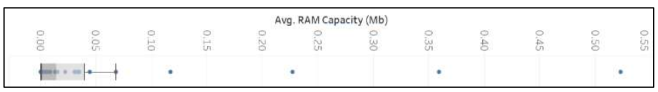

Fig. 9. Statistics of average RAM each year from 1989 to 2013.

This statistical measure for RAM leads us to create bins for the RAM and classify the devices into 4 types as given:

Table 2. Types of Mobile devices based on RAM

Types of Mobile Devices based on RAM		
Type	**Minimum RAM**	**Maximum RAM**
Flip-phones	0	0.03
PDAs	0.03	0.157
Tablets	0.158	0.375
Smartphones	0.376	1.00

We further supplemented this statistical division of mobile device types through visualizations, more specifically using a cluster visualization using tableau, Figure10. The cluster plot further confirmed our theory of the 3 devices based on RAM.

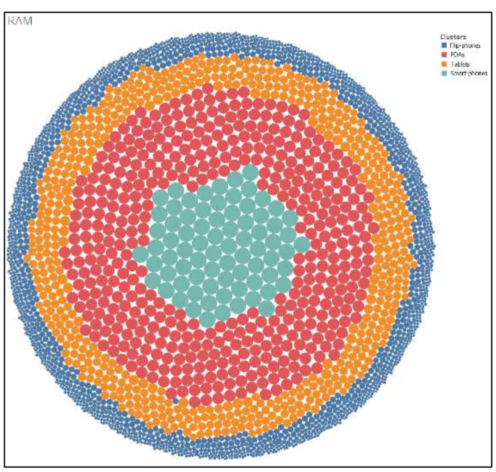

Fig. 10. Cluster plot for mobile Device types based on RAM.

Using the mobile device types, we further evaluated the trends which followed the mobile devices through the years.

V. Trends observed for Defined Mobile Types

Now that we divided the mobile devices into 4 different types, in this part, the development trend of these four types of mobile devices will be shown through the line graph.

Line graphs are generally considered the best choice for visualizing time series data. Line charts can be used to identify trends and changes in a period, emphasize the trend of data fluctuations and can represent continuous time series [10]. Therefore, the line graph is selected to show the development trend of different types of mobile devices. The horizontal axis represents the release year of mobile devices, and the vertical axis represents the number of mobile devices.

Different colours have been used to represent the different mobile device types and make it easier to visually distinguish the same.

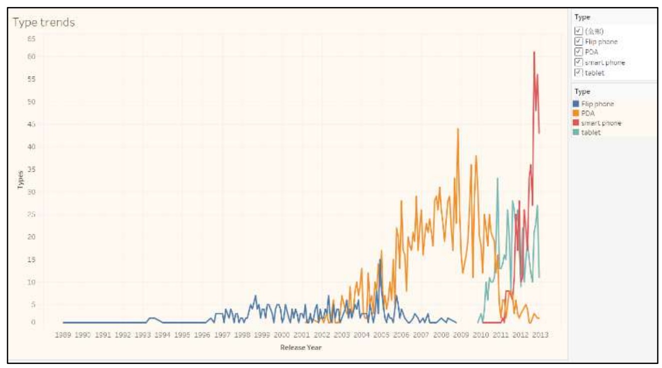

Fig. 11. Life of the different mobile devices between 1989 to 2013.

In the graph, the blue line represents flip phones, orange line PDAs, green line for tablets and the red line for smart phones. A filter is added to filter different types of mobile devices, to observe the development trend of a single type more clearly or compare the development trend of two different types of mobile devices.

A. Trends of the Flip-Phones

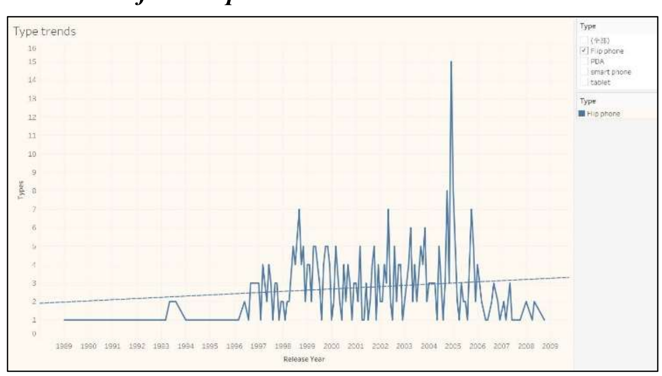

Fig. 12. Life of the Flip-phones.

Flip phones have not developed well since it was released from 1989 until 1996. The trend was relatively stable.

The RAM capacity of its model ranges from 0MB to 0.03MB. Since 1996, the release of flip phones increased, reaching the peak in 2004, with 39 models released in that year. However, beginning from 2005, the flip phones have been gradually replaced by other types of mobile devices. Finally in 2009, there was not a single model of flip-phones released. Overall, the peak of flip phones is relatively long, from the second half of the 1990s to the first half of the 2000s. This type existed for 20 years.

B. *Trends of the PDAs*

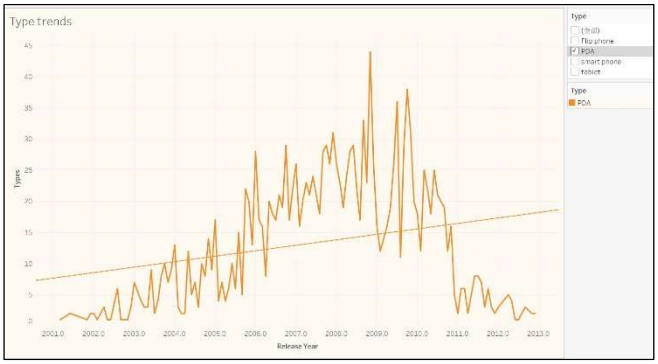

Fig. 13. Life of the PDAs.

The development trend of PDA is more tortuous than that of flip phones. The RAM capacity of its model ranges from 0.03MB to 0.157MB. Since its release in 2001, it has been on the rise. In the period, 2006 to 2009, the development of PDA reached its peak. Since then, PDAs have gradually replaced flip phones and become the mainstream of mobile devices. However, since 2010, the development of PDAs has shown a downward trend, and it finally ceased production in 2013. Overall, PDAs has gone through 12 years from appearance to disappearance. Its rise and decline are relatively fast, where the decline is faster than its rise.

C. *Trends of the Tablets*

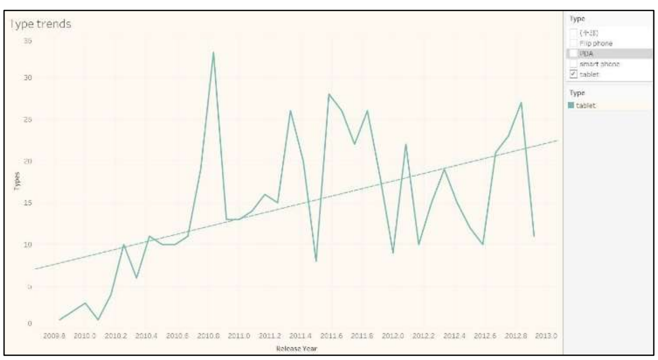

Fig. 14. Life of the tablets.

When flip phones were just abandoned and PDAs were in full development, tablets began to develop quietly. The RAM capacity of its model ranges from 0.158MB to 0.375MB. It only took just one year since its first release to become popular, and by the time of visual display in 2013, it has no obvious downward trend. Perhaps the birth of smart phone has affected the development of tablet to some extent which caused the sharp drop of the number of model releases for the tablets.

D. *Trends of the Smart Phones*

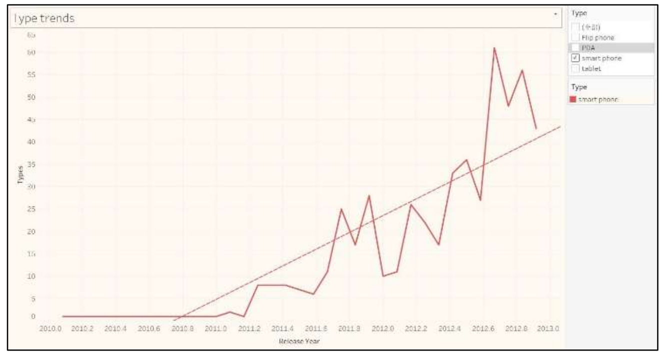

Fig. 15. Life of the smartphones.

The trend of smart phone is like that of tablet. The RAM capacity of its model ranges from 0.376MB to 1.00MB. They are both mobile devices that have begun to develop in recent years, and the trend of rise is very significant in the short term. But compared with the tablet, it appeared later and developed faster. Within two years, the sheer number of models produced exceeds that of the total initial release of the flip-phones, PDAs and the tablets combined. More and more companies have participated in the development of smart phones starting from 2011.

E. *Insights drawn from the life of the mobile devices*

In general, flip phones were the earliest and popular mobile devices which tried to stay on market for 20 years before disappearing. Because the development of mobile devices was still in its infancy and there were very few device models to compete, it lasted for 20 years. It was replaced by new types of mobile devices as the development of RAM progressed in the years. PDAs were the second type of mobile devices which came into existence during the fall of the era of flip-phones. PDAs had been popular for about five years. During that time, no other type of mobile devices could shake its hegemony. Since the 2010s, diversified mobile devices have appeared in the mobile device market and developed rapidly. As a result, the trend of PDA also rapidly decreased and disappeared from the market. The smartphones and tablets are the 2 mainstream mobile devices which have absolute control over the market. According to the limited data provided, the Tablets and Smartphones developed quite quickly compared to the initial release of mobile devices and have seen to be in an upward trend with the number of models being released since 2010. Out of all 4 mobile devices, the smartphones are the mobile devices with the most prospects considering the steep incline of its trend. The lifespan of each of the device is given in more detail in the following images:

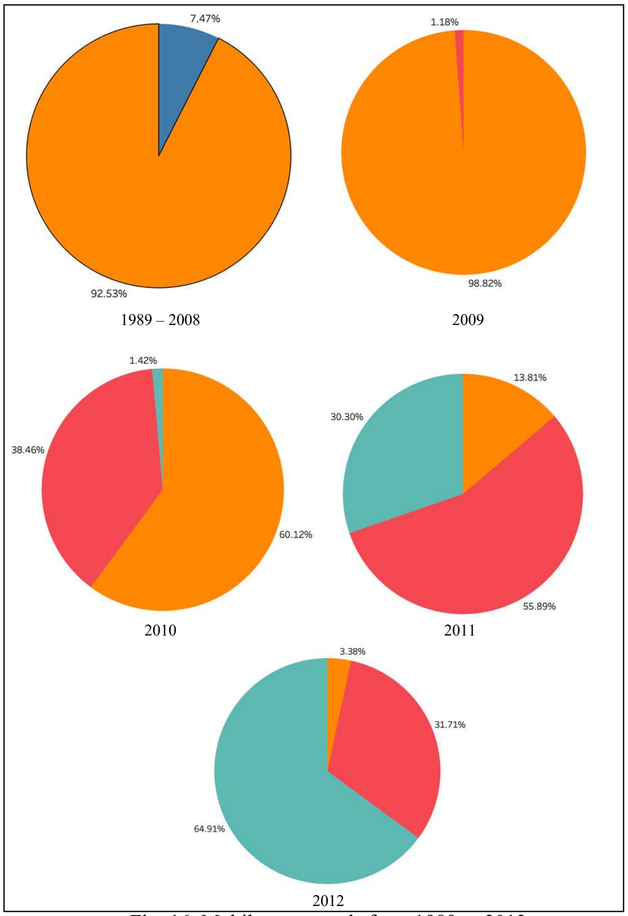

Fig. 16. Mobile type trends from 1989 to 2012

VI. Predictions for Mobile Type emergence

A. *Attributes and graphs used for predictions*

We use RAM (memory), capacity (Megabyte), Storage capacity (Megabyte), CPU clock (MHz), Display size (dimensions) (diagonal in inch, width and length in pixels), Volume (width-length-depth in mm), Mass (grammes), Pixel Density (per inch) for predicting new mobile device types, and changes in new mobile devices are judged by changes in different dimensions. To make predictions from the data, we can use Tableau's predictive modelling functions. To make data-driven predictions, we can first use Tableau's predictive modelling capabilities to compare the prediction function's results with actual values. Then the data prediction evaluation is carried out using gap and image analysis. Finally, we can use a combination of type analysis and image analysis to detect the emergence of new mobile device types.

Obviously, pie charts, bubble charts and some graphs do not clearly show trends and forecasts. The data is visible in bar and column charts, but no obvious trends are visible. Then, using a line graph for trend visualisation, we can see how the RAM, capacity, Storage capacity, CPU clock, Display size, volume, mass, and pixel density of mobile devices change over time.

B. *Construction of the predictive visuals*

Because the distribution of the data is so uneven, we chose the maximum, average, and minimum values for the Y-axis and time for the X-axis. The trend changes of the three can be clearly seen from a graph by arranging the three values of the maximum value, the average value, and the minimum value on the Y-axis at the same time, which is helpful for users to analyse and compare. Simultaneously, we consider the user's visual perception and experience, and the light-coloured background with warm colours can relieve visual fatigue. The maximum, average, and minimum polylines are represented by the red, orange, and blue lines, respectively. In general, red represents enthusiasm and the rolled-up line of greatest value. The colour orange represents vitality, energy and moderation, a polyline representing the mean. Blue is a gentler colour that represents a polyline with a smaller value. This assists users in capturing information and generating associations. The instructional approach of arranging the three-color polylines together not only clarifies the trend but also makes comparative analysis easier.

For the forecast section, the forecast visualization shown in the image below uses data from 1998 to 2009 to forecast data from 2010 to 2013. The X-axis is a month-by-month time series (Contains the forecast time used and the time it was forecasted). The Y-axis represents the mean value of RAM, capacity, Storage capacity, CPU clock, Display size, volume, Mass, and Pixel density, as indicated by the axis labels. This axis ordering allows us to see the data forecast clearly through the horizontal polyline. The original data is represented by the unshaded line, and the predicted data is represented by the shaded line. Similarly, users can clearly see the predicted curve using the forecast visualization line chart. We chose clear and concise titles because we want users to have a good visual experience. We use trend lines to predict the continuation of a certain trend of a variable. It also helps to identify the correlation between X and Y, variables by observing the trend in both simultaneously. We chose a light background colour to alleviate the user's visual fatigue. We wanted users to be able to see the polyline trend clearly, so we chose a more distinct colour. Figures below show the trends and forecasts for the maximum, average, and minimum values for mobile devices of various dimensions.

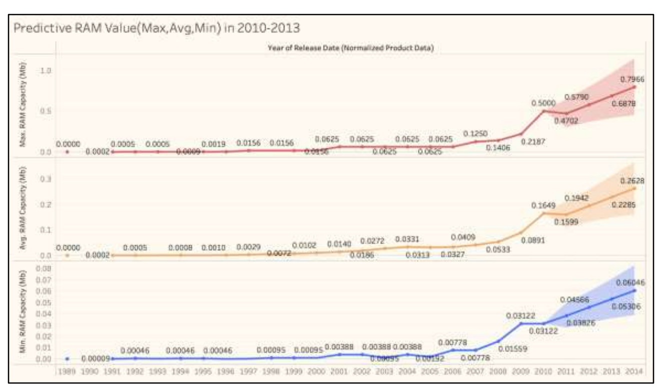

Fig. 17. RAM value trends and forecast.

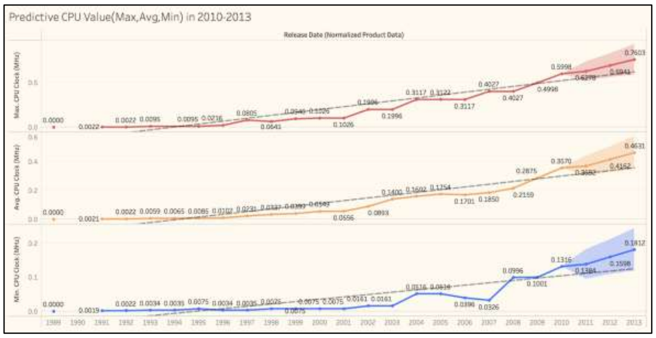

Fig. 18. CPU value trends and forecast.

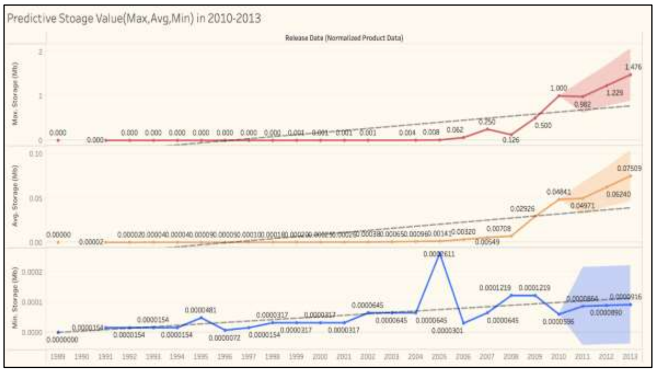

Fig. 19. Storage value trends and forecast.

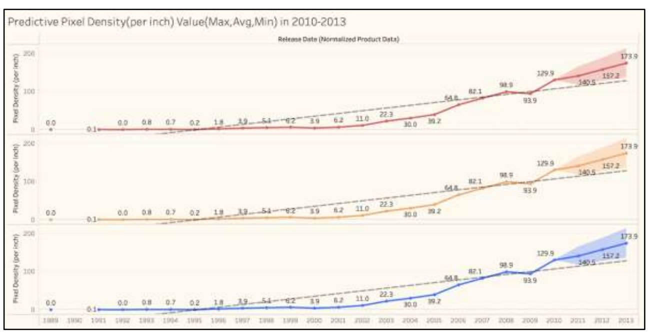

Fig. 20. Pixel Density value trends and forecast.

C. Analyzing the visuals

We analyze the forecast data by using data visualization. For example, if we only have data from 1989 to 2010, we can predict the new types of attributes that will dominate between 2011 and 2013 using different data dimensions. Mobile device pixel density, CPU, storage, and RAM are all increasing. By comparing maximum and average values, these properties are improving for mobile devices. Based on the minimum trend, these properties are also relatively stable and rising. We can imagine an upward trend by visualizing these mobile device properties.

The user will then be shown how the predicted value compares to the actual value. We can tell there is a difference between the predicted and actual values by comparing the visual data. On the one hand, these gaps result from data inconsistency; on the other hand, we require more comprehensive data.

The following are comparison of actual and predicted values for CPU values and comparison of actual and predicted values for RAM values, respectively. We use a warm light background to reduce visual fatigue and use different colored curves to make the data more visible. The time series is still on the x-axis, and the actual and predicted values of max, mean, and min are on the y-axis. We constantly adjust the colors and lines during the visualization process to achieve the best visualization effect.

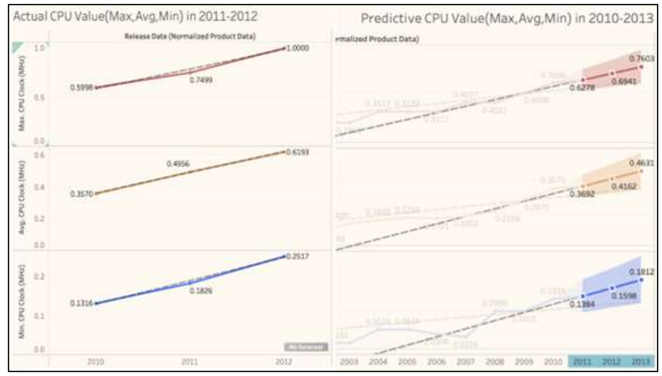

Fig. 21. Comparison of actual and predicted values for CPU values.

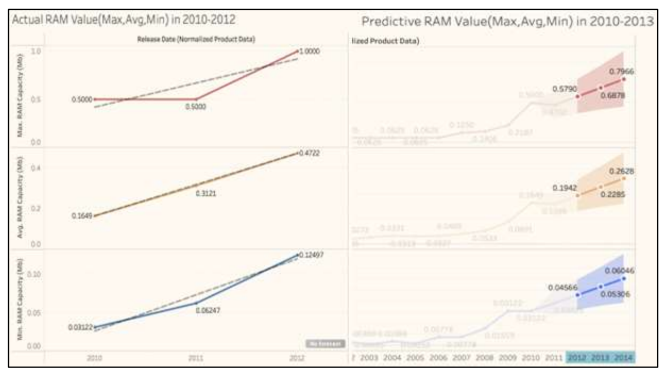

Fig. 22. Comparison of actual and predicted values for RAM values.

VII. Evaluation of Visuals

A. Evaluation method

Evaluation is an assessment of visualization to see if benefits have been provided, in this case, if the relevant information has been delivered through the visualizations used. Of the 4 major evaluation methods taught to us, we chose the questionnaire as our evaluation method [11].

A questionnaire is a qualitative technique for which the results can be quantified. We prepared a questionnaire with our visualizations and simple questions to receive feedback for the visuals. The assumption was based that each of the surveyed were students from the same course. This was a mandatory step to target audience who could give valid input for the visualizations based on the lectures.

B. Expectations from the surveyees

We had the following expectations of the surveyed:

- Receive constructive feedback on the visualization.
- A valid reason to why they suggested the change in visualization if any.

C. Feedback from the surveyees

We released the survey and garnered responses from 7 different groups from which the most substantial were groups RE-04-G05 and CC-08-G06. Through their answers to our questions, we were able to modify the visualizations as per recommended and produce visuals which are easily understood and interpreted. There were a few more groups which answered our survey, but the answers were positive and did not ask for many changes nor have many suggestions.

D. Changes in the visuals

Based on the most valued feedback received, we updated the visuals accordingly and personally asked the 2 groups for further feedback. The visuals were even better understood by them, and they had no further suggestions. The following are the visuals we asked suggestions for and received constructive feedback.

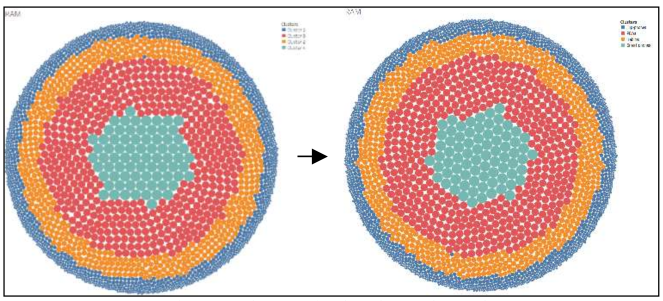

Fig. 23. Changes in the cluster legend.

The most common feedback between the 2 groups was the inappropriate legend. Both groups asked to include the actual types of mobile devices rather than the cluster names. This led to the change as seen in Figure 23.

Lastly for Section V, the 2 groups recommended the trend lines to be visible to aid the visuals for the viewers. Based on this feedback we added the trend line for every graph in Section V. The change looks like the following:

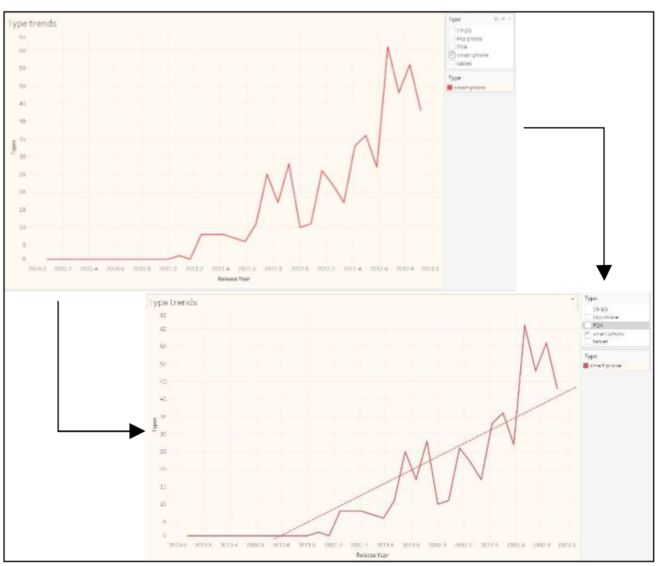

Fig. 24. Addition of the trend lines to the visuals.

VIII. Conclusion

The types of mobile devices have greatly increased over time, resulting in a rapid increase in data in recent years. Prediction through data changes in different dimensions can predict the future trends of various mobile device attributes. For example, through this data we can predict the exponential growth of the smart-phones and a plateaued production period for tablets. We could also see the flip-phones and the PDAs going obsolete.

Consequently, we can say that for users viewing data visualizations, clearly visible and useful data is critical. The visualization is influenced by the visual variables chosen, the data arrangement, and all interactions. We believe that as new devices emerge, more new properties will be required to define new types of mobile devices.

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