Mobile device market change

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I. Introduction

Trend analysis provides insights of the trend of the current businesses' operations based on the past information on products to an emerging business. The current study aims to identify the trends of types of mobile devices, thereby predicting the trend of the type of newly emerging mobile devices. Such study will provide insights into the future market shifts and directions of the emerging mobile devices, and enable a business to make better decisions such as resources allocation and target

The normalised product data consists of 16 different qualitative and quantitative features of electronic devices, and the normalised product data consists of information of 3,162 different mobile devices. The data presents performance, display and comfort characteristics with the release dates in ratio scales.

TABLE I
Features and structures of the normalised product

Data		Quality	
Feature	Types of Scales	Type	Measure
Model	Nominal	Qualitative	Name
Model ID	Nominal	Qualitative	Model ID
Release Date	Interval	Quantitative	Date
Release Year	Interval	Quantitative	Year
RAM Capacity	Ratio	Quantitative	Mb
Storage	Ratio	Quantitative	Mb
CPU Clock	Ratio	Quantitative	MHz
Display Diagonal	Ratio	Quantitative	in
Display Width	Ratio	Quantitative	px
Display Length	Ratio	Quantitative	px
Width	Ratio	Quantitative	mm
Length	Ratio	Quantitative	mm
Depth	Ratio	Quantitative	mm
Volume	Ratio	Quantitative	cubic cm
Mass	Ratio	Quantitative	grams
Pixel Density	Ratio	Quantitative	per inch

II. Part A, types of mobile devices

A. Pre-processing

For our pre-processing, the measurement of the first model was not recorded, thus, the first model was removed for the trend analysis. *Release Year* was initially not consistent with *Release Date*. For example, the release year was labelled as 2013 for some of the devices that were released at the end of 2012 in the release date. Thus, *Release Year* was adjusted based on the year of *Release Date* for consistency purposes. In order to enable more intuitive visualisation of the trend for the businesses, several quantitative attributes in the normalised product data were combined into a single attribute through summation based on their representation. *RAM Capacity, Storage* and *CPU clock* were summed up row-wise, and we derived a new attribute, *Performance rating*, as aforementioned attributes indicate the performance aspect of an electronic device. Therefore, *Display Diagonal* and *Pixel Density* were summed up to represent the *Display rating*. Lastly, *comfort rating* was derived by subtracting *Depth* and *Mass* attributes from the *Size* attribute. Summation or subtraction across different attributes was feasible, as all quantitative attributes in the normalised product data were in the same scale due to normalisation.

B. Visual proof and derivation

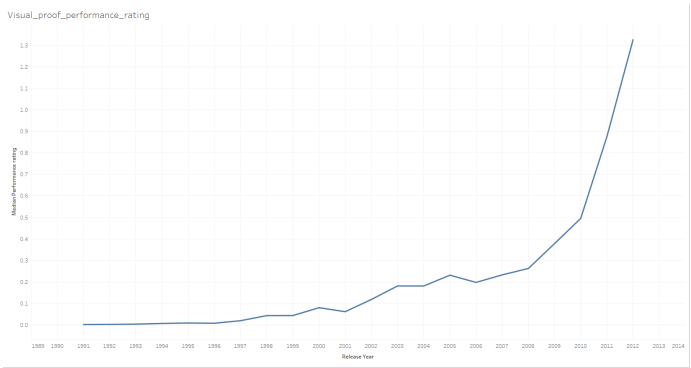

Fig. 1. Median performance rating over years.

This visualisation [Fig.1] demonstrates that with the increase of years we have a gradually increased "median performance rating" from 1991 to 2012, this trajectory holds true for our assumptions of newer mobile devices having better performance, which prove that the design of the "performance rating" does reflect the mobile devices' performance as intended. By arranging the median of performance rating at the vertical-axis and years at the horizontal axis, it allows us to clearly see the changes of performance rating over the period of years.

Also it shows that comparing mobile devices with a large difference in release years is unreasonable as newer devices

will always hold better performance thus we use 4 years as a period of time to compare devices.

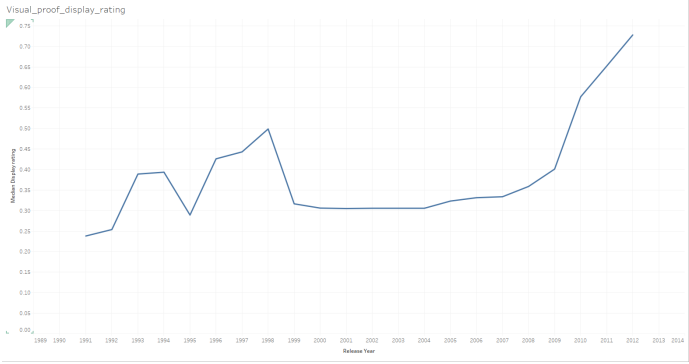

Fig. 2. Median display rating over years.

This visualisation [Fig.2] also arrange median value at the vertical axis and years at the horizontal axis for the same reason as [Fig.1], it demonstrates that with the increase of years we have a period from 1991 to 1998 where the mobiles have a general trend of increase in median display rating followed by a big drop in median display rating in 1999 and then gradually increase from 2000 to 2012. Although there exists two major decreases in “median display rating” in both 1995 and 1999, the general trend of the “median display rating” is still increasing over years. Which also proves that comparing mobile devices with a large difference in release years is unreasonable as newer devices will more likely to have better displays than older devices.

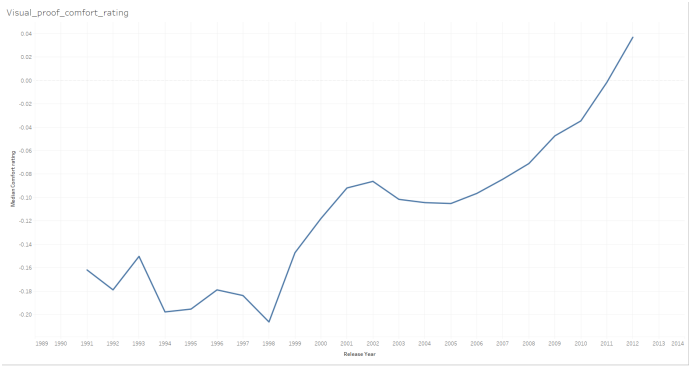

Fig. 3. Median comfort rating over years.

This visualisation [Fig.3] has the same arrangement as [Fig.1.2], it demonstrates that with the increase of years the period from 1991 to1998 has fluctuated “median comfort ratings” and after 1998 it starts to have a general trend of increase in comfort ratings. Which also proves that comparing mobile devices with a large difference in release years is unreasonable as newer devices will more likely be more comfortable to use than older devices.

The visualisations [Fig.4.5.6] are the 1989-1994 performance, display and comfort rating for each device, by listing all the model’s name at vertical axis and rating at horizontal

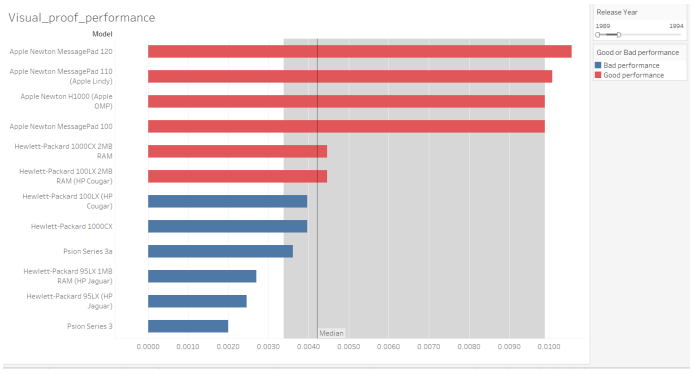

Fig. 4. Performance rating for devices from 1989-1994.

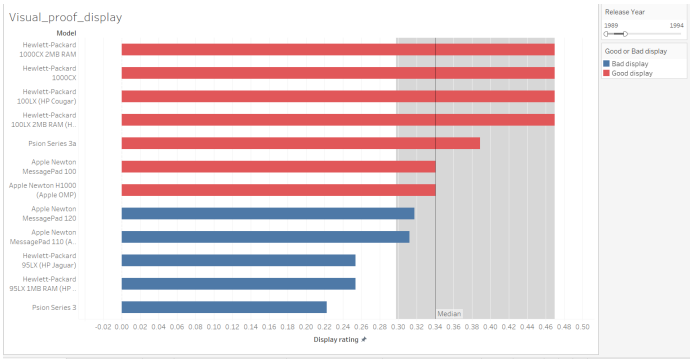

Fig. 5. Display rating for devices from 1989-1994.

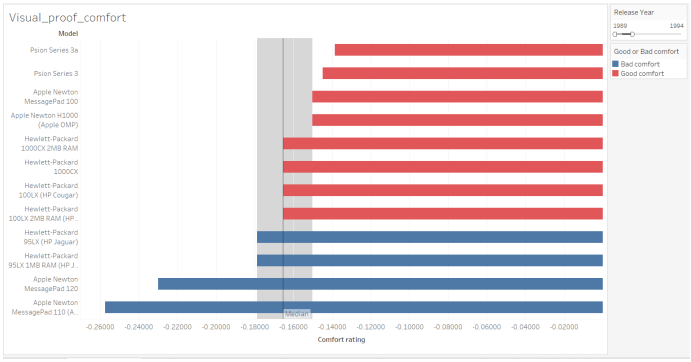

Fig. 6. Comfort rating for devices from 1989-1994.

axis with the descending order, it demonstrate how devices from each period been separate into Good and Bad categories for each feature. As the mobile devices have better ratings than the median in each period , it would be put into a good category and bad otherwise. The different colors and the median line are the visual variables we used. These visual variables helps clarify which category each model have been placed into.

With this approach, we obtain the result of a visualisation of devices that have common characteristics.

C. Type identification

Each performance rating, display rating and comfort rating column was converted into a categorical/nominal variable. In consideration of the speed of technological advancement shown in [Fig.1.2.3], the models were compared in a separate manner by every 4 year period to facilitate a reasonable comparison across the models that were developed in different time periods. By using the filter interaction that implemented in [Fig.1.2.3] we are able to segmented the years we want for each 4 years period and see how the models been separated. The median of each column every 4 year time period was used as the criterion for categorising "Good" or "Bad". The median was used instead of mean to prevent a high influence of a low and large value.

The first letter indicates the categorical rating in performance followed by display and comfort, and the letter G represents "Good" while B represents "Bad". The summary of type is shown in [Tab.II]. If the devices have the same encoding, then it will share the common features, thus, we obtained eight different types of devices.

TABLE II
IDENTIFIED TYPE AND DESCRIPTION

Type	Description
GGG	Well-distributed
GGB	Comfort-deficient
GBG	Display-deficient
BGG	Performance-deficient
BBG	Comfort-focused
BGB	Display-focused
GBB	Performance-focused
BBB	Deficient

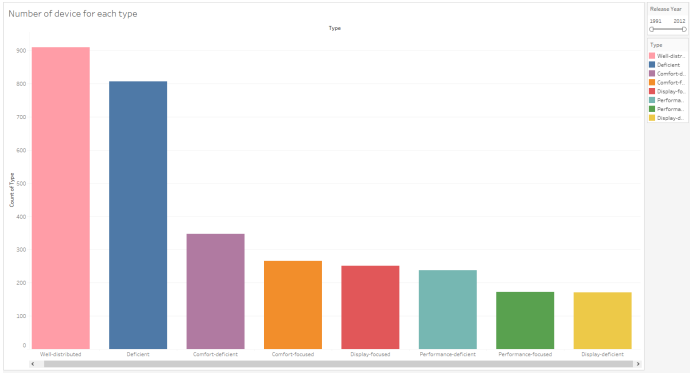

Fig. 7. Frequency of each device type

As the visualisation [Fig.7] shown, there are 8 different types of mobile devices base on their common features in descending order from left to right. It placed the number of devices in vertical axis and the type name on the horizontal axis. By using different colours we can visually tells that each bar represents different types.

The well-distributed and deficient devices are top-two types of devices that have relatively large frequency compared to other types. Comfort-deficient comes third and Comfort-focused, Display-focused and performance-deficient share similar frequency. At last we have performance-focused and display-deficient devices.

D. Evaluation of original visualisations

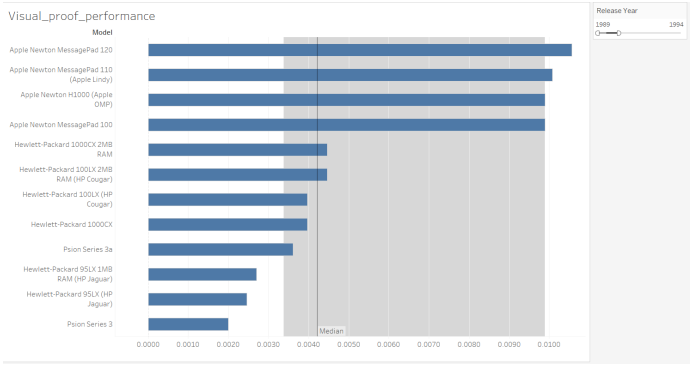

Fig. 8. Original performance rating for devices from 1989-1994.

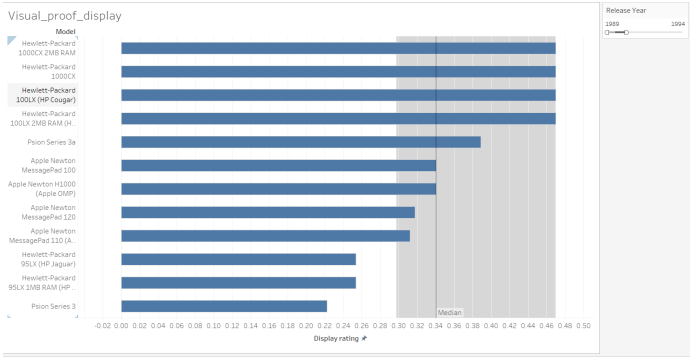

Fig. 9. Original display rating for devices from 1989-1994.

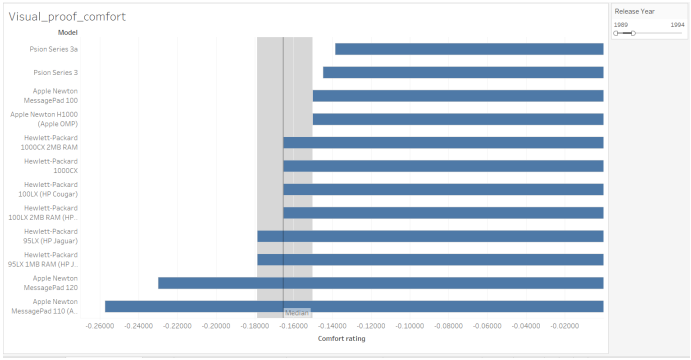

Fig. 10. Original comfort rating for devices from 1989-1994.

[Fig 8.9.10] were the original visualisations of rating attributes to show the cut-off of differentiating "Good" or "Bad" devices of each rating metric.

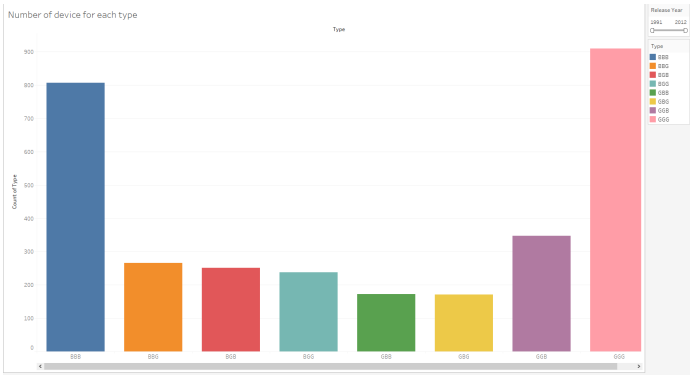

Fig. 11. Original Frequency of each device type

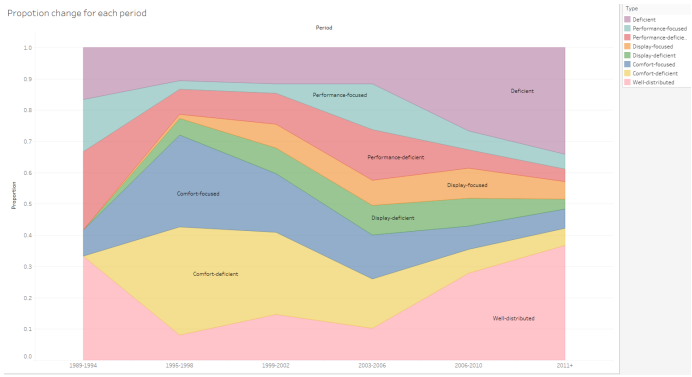

Fig. 12. Area plot of change in proportion of mobile types over the periods

1) interviews: Open-ended interview of several peers was done to identify the shortcomings of the original visualisations based on how interviewees perceived or interpreted the original visualisation. The participants are from group CC-04-G06 and CC-02-G01. After gathering the response, we identified that the common answers from the interviewee.

For [Fig.8.9.10]:
- No legend thus hard to tell if each device belongs to "Good" or "Bad" category.

For [Fig.11]:
- 3 digit encoding not interpretable
- Results unordered, which makes the visualisation hard to compare the frequency

2) improvements: Addition of legends and colour was used to differentiate the good and bad for each common feature in [Fig.8.9.10]. To enable more interpretable visualisation, the horizontal axis labels were renamed to the corresponding types that were defined in [Tab II], and the bars were juxtaposed in descending order based on the frequency.

III. Part B

A. pre-processing

Based on the previous part, we have divided the time into 6 periods and mobile devices into 8 types. In order to observe the trends regarding different types of mobile devices, the proportion of each mobile device in each period was calculated.

Firstly, we group the types of mobile devices for each period and count the number of each type. For species that did not appear in each period, we set the count to 0. Then the formula is used to calculate the proportion of each species in different periods. Finally, the data from six periods are combined to produce visualisations.

B. Visualisation of trend over period

We created an area plot to achieve our interactive visualisation, with the proportion of the device type at the vertical axis and periods at the horizontal axis as it can show the change of proportion for each period more clearly than the line plot, bar plot and also pie chart we tried. In the [Fig.12], each colour of area refers to one of the 8 types as shown in the identified type and description table above. The abscissa represents the different periods and the ordinate indicates the amount of proportion each type contributed to. Specifically, the difference between the highest and lowest point in the specific period represents the proportion. For example, period 1 estimates the proportion of 'well-distributed' and 'deficient' from 1989-1994, which both account for 0.33 and 0.16 respectively.

Overall, each type experienced significant fluctuations throughout the periods. From 1989 to 1998, the fluctuations can be broadly divided into two patterns. The proportions of mobile types which are defined as 'well-distributed' and 'deficient' decrease significantly from 0.33 to 0.08 and 0.16 to 0.10 respectively. Similar trends are shown by 'performance-deficient' and 'performance-focused'. These four types could be seen as the main components of the original mobile phone market. However, the proportions of other types all increase obviously, especially for 'display-deficient', 'comfort-deficient', and 'display-focused' which did not appear in the period1. 'Comfort-focus' and 'comfort-deficient' occupied a larger market together in this period. This can be explained by that in the early days, the types of mobile phones were relatively limited. Developers were focusing on exploring mobiles, rather than improving different properties. After a few years, researchers were starting to further develop other properties such as comfortable capability and display. Therefore, the types of phones were no longer broadly classified as just well-distributed or deficient, and different kinds of model devices appeared on the market. Interestingly, comfort determines the two extremes of the mobile market.

During 1995-2002, 'well-distributed' were increasing continuously due to improved developments and 'deficient' kept a stable trend. At this stage, developers focused on improving one of the specific aspects. At the same time, the proportion of most other types of mobiles increased slightly, besides 'comfort-focused' and 'comfort-deficient'. It indicates that the mainstream of the market has gradually shifted from comfort to other rating features. In the following years up to 2006,

the previous trends kept going except ‘well-distributed’, which experienced a slight drop.

However, from 2006, due to the advanced science and technology, more and more mobiles are able to perform well in multiple capacities at the same time. Then, the mainstream of the mobile market is back to ‘well-distributed’ and ‘deficient’. With the increasing trend of ‘well-distributed’ and ‘deficient’, almost up to 0.7, other types gradually reduced, just accounting for a similar small proportion of the market. This means that developers are trying to enhance other features for a better customer experience, based on the already improved one. If the update is successful, it is classified as well-distributed, and if it is eliminated through selection or competition, it is transformed to deficient.

In conclusion, the types of mobile devices have fluctuated greatly over the two decades. At the beginning, the development of mobile phones was not mature and the product categories were not complete. With the development of technology, there are more types of mobile phones in the market and iterations occur. As a result, consumers have more choices and preferences, and they can choose the appropriate products based on the attributes of the mobile devices. Then the manufacturer may reduce or increase production of a certain type in response to customer preferences. Finally, as the technology matures, there is a survival of the fittest between products. Some products are classified as ‘well-distributed’ after iteration, while others may be gradually eliminated by the market.

C. Evaluation of original visualisations

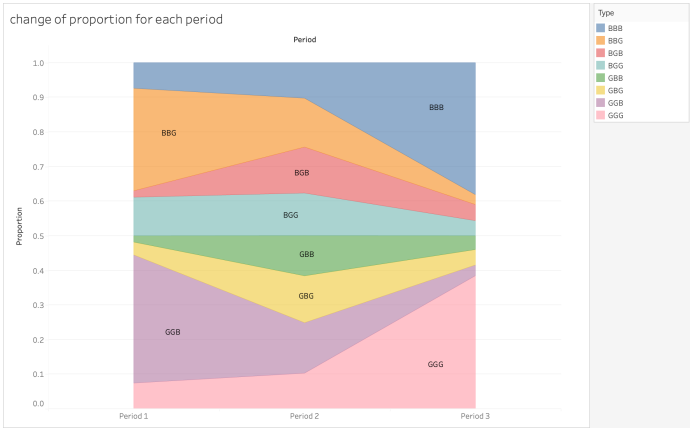

Fig. 13. Original Area plot of change in proportion of mobile types over the periods

[Fig.13.14] were the original visualisations of proportion to show the trends of different mobile devices.

1) interview: Open-ended interviews of several peers were done to identify the shortcomings of the original visualisations based on how interviewees perceived or interpreted the original visualisation. The participants are from group group CC-04-G06 and CC-02-G01. After gathering the response, we identified the common answers

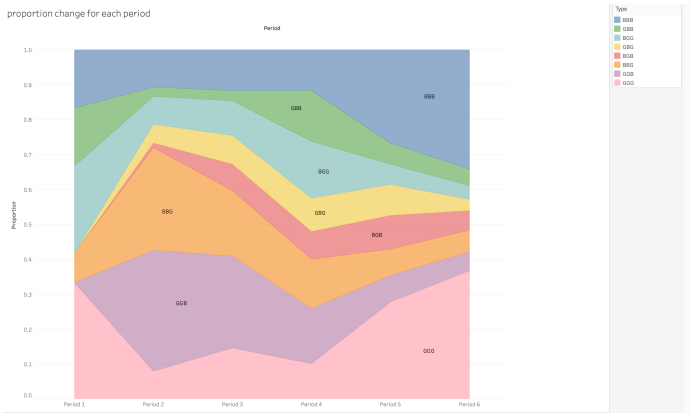

Fig. 14. Original Area plot of change in proportion of mobile types over the periods

from the interviewee.

For [Fig.13]:
- The trend is not readily discernible as there are only three periods of data
- Area plot is less common in visualisation and require a clearer description of the background

For [Fig.14]:
- 3 digit encoding not interpretable
- No legend thus hard to distinguish the specific year of each period

2) improvements: The three periods we initially used were redefined into six periods, in order to better show the trends. To enable more interpretable visualisation, the horizontal axis labels were renamed to the corresponding years that were defined in pre-processing, and a more detailed description will be explained.

IV. Part C

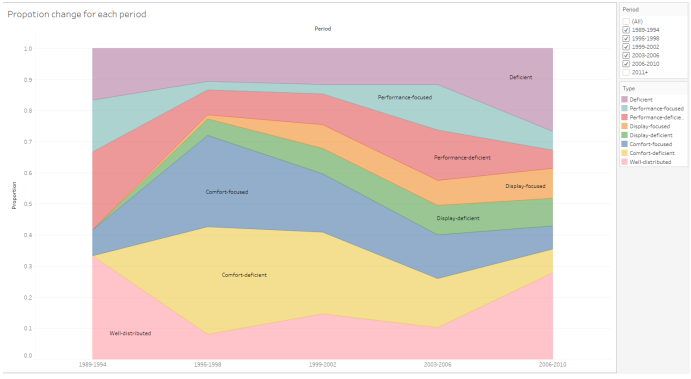

Fig. 15. Area plot of change in proportion of mobile types over the periods pre 2011

In order for us to anticipate the newly emerging mobile device type, area plot was implemented. The periods of years

are arranged on the horizontal axis and as there was a high variation in number of new device each year, the use of proportion on the vertical axis instead of number allows us to observe the change in trend more clearly by preventing dominance of extremely large values. Retinal variable, colour, was used for types of devices that visually incorporate the third dimension and perceived different colour as different types.

As demonstrated from [Fig.15] the proportion of each mobile type fluctuated significantly throughout the periods. In the earliest period, the proportions of the types of the emerging devices are similar with the exception of the display deficient, comfort-deficient and display-focused mobiles. From 1995 to 1998, the mobiles, which belong to display deficient, comfort-deficient and display-focused categories, newly emerged, and the majority of the newly emerging devices were either comfort-deficient or comfort-focused type. Such a trend from 1995 to 1998 was preserved in the next period (1999 to 2002) with a slight increase in proportions of display-focused and display-deficient types and modest decrease in proportions of comfort-focused and comfort-deficient types. The proportions of mobile types between 2003 and 2006 were evenly distributed, and there were no prominent features that were targeted to be developed in particular. However, from the latest period in [Fig.15], there was a significant increase in proportions of deficient type and well-distributed type, and the number of newly emerging devices that belong to a single aspect-deficient or a single aspect-focused type were proportional but constantly decreasing.

In consideration of the overall trend and the previous period, the tendency of mobile business to focus on developing well-distributed or deficient types of mobiles is observed. In this regard, the trend of types of mobile devices is anticipated that there will be a further increase in proportion of well-distributed and deficient types.

A. Comparison of anticipation and the actual output

The trend of the types of mobile devices after 2011 was anticipated that mobile devices will focus on developing either deficient and well-distributed mobile devices rather than other types, and we anticipated further increase in proportion of deficient and well-distributed mobile devices. The actual trend is presented in [Fig.12], and the anticipated trend coincides with the actual trend. From 2006 onwards, the mobile businesses began to focus more on developing well-distributed or deficient mobiles.

V. Limitation and Conclusion

Price is an important factor in predicting the trend of mobile phone types more accurately. The credibility is diminished when the prediction is made solely based on the previous trend visualisation. Moreover, at the peak of the diversification of mobile phones, the potential reasons behind the upgrade and elimination are based on our assumptions. More references and background checks during the developing period are needed to explain these changes for interpretability and reliability.

Additionally, in our visualising of trends, we only used the grouping data of mobile types. Thus, involving mobile models and the company in visualisation could be beneficial for further investigations in company-specific trend analysis.