A Case Study of the Health of an Augmented Reality Software Ecosystem: Vuforia

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Abstract. Augmented Reality is becoming increasingly popular. The success of a platform is typically observed by measuring the health of the software ecosystem surrounding it. In this paper, we take a closer look at the Vuforia ecosystem's health by mining the Vuforia platform application repository. It is observed that the developer ecosystem is the strength of the platform. We also determine that Vuforia could be the biggest player in the market if they lay its focus on specific types of app development.

1 Introduction

Software ecosystems (SECOs) are sets of businesses functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. The inability to function in a software ecosystem has already led to the demise of many software vendors, leading to loss of competition, intellectual property, and eventually jobs in the software industry [1].

Vuforia is a platform for Augmented Reality (AR) that provides Application Programming Interfaces (API) in C++, Java, Objective-C, and the .Net languages through an extension to the Unity game engine. With the use of 2D and 3D targets, AR gives a new way to perceive the environment around combining virtual to real. Vuforia was introduced by Qualcomm five years ago and has become an industry-leading platform that has been supported by a global ecosystem of developers. Vuforia was sold to PTC Inc. in 2015 and supported a global ecosystem of 175,000+ registered developers and has powered 20,000+ apps with more than 200 million app installs worldwide [2].

The research question we try to answer is *"Can Vuforia improve its position in the market of AR platforms?"* To that end the focus is on the involvement of the developers and the analysis on the categories, maturity and ratings will show us the position of Vuforia in the AR mobile app market. For instance if the developers seem to be active, then Vuforia should focus on other parts to improve the health of their ecosystem to get a better position in the market, for example their marketing approach or their position in the mobile ecosystem.

2 Research Method

To measure the longevity and propensity for growth, as we define software ecosystem health, of Vuforia a combined qualitative and quantitative research

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is performed. The developer's website is the main source of information for this study. Forums on the developer network page provide information about Vuforia's developer ecosystem. These forums are important to get an insight on the developer's point of view on the ecosystem they shape and their opinion on the changes between Qualcomm and PTC.

A study from 2013 by Chen et al. [3] introduces the maturity ratings by both app providers, App Store and Google Play. With some minor differences the maturity rating defined by minimum age is more regulated with the App Store than Google Play. It provides a maturity rating based on the content of the app with a minimum age of "4+", "9+","12+", or "17+". In accordance, the health measurement of the Vuforia applications is conducted within the AppStore only. The apps are extracted manually in a table by name, category, customer rating, maturity rating (rating based on minimum age), and provider. We expect that AR will mostly be used for gaming. We state the following hypothesis:

- H1: Less serious categories get more ratings.
- H2: Apps with immature content get lower rates.
- H3: Apps with mature content are paid over apps with immature content.

We use Import.io [4], a Web Data Platform and free Web Scraping Tool, to extract the needed data. With the tool's feature "*bulk extract*", which runs the extraction method into multiple links at the same time, it is possible to extract all data into tables from all paginations of the forum. The extracted data which includes the discussed topics, the developer's name, the number of views and replies provides also an insight into the time line of the Vuforia platform since 2011.

3 Analysis and Results

3.1 The Developers Network and Applications

The extracted data from the forum of the website helps to determine how many actual active actors there are among the developers. Currently the website is changing as new topics are being added every day. Measurement on SPSS is conducted in the data gathered previously from the forum. From the data it has been determined that 4,803 different developers have created one topic or more in the forum. And the first five most active users have respectively posted between 125 and 61 topics. The first actor started being active in 2012, the second in 2010, the third in 2011, the fourth and the fifth in 2013.

The data mining tool import.io has been used for extracting the topics discussed in the forum webpage, the number of replies and views, the name of the active developer who posted the subject and the date of posting. The forum consists of 11,248 topics, 63,353 posts and 184,289 users (developers) [5]. Within the forum three topics have been created: News & Announcements, FAQ and the AR Technical Discussion. The AR Technical Discussion consists itself of a range of topics which have been added by developers.

The analyzed apps are extracted from the marketing website of Vuforia [2]. The app data was collected and listed manually in a table with name, category, satisfaction rating, maturity rating and the provider. After extracting only the apps available in the EU App store, and only the apps of which the wanted information was available, 848 apps have been analyzed.

Figure 1 shows the rating of the apps which varies from 1 to 5 stars in the App Store. Most of the apps did not have enough ratings to calculate an average. We can also see that the apps that have been rated, received a high rating, around 4 and 4.5 stars.

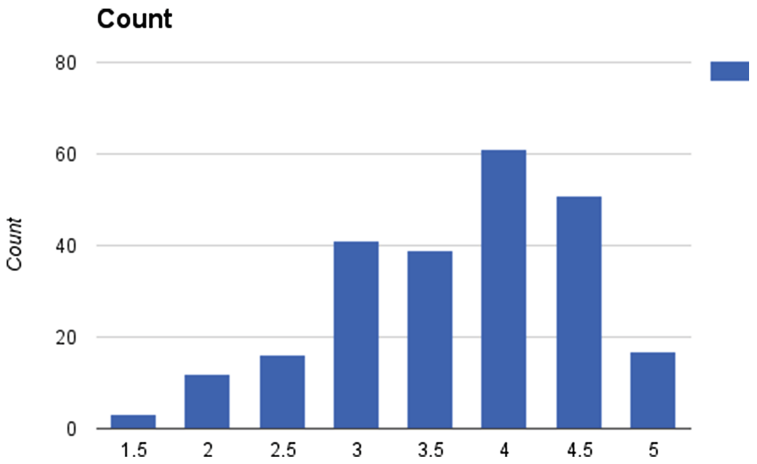

Fig. 1. Counted customer ratings of Vuforia's Apps

To see if the apps that use Vuforia make profit on sales, the data on the price of the apps have been collected. The percentage of free apps and paid apps is considerably different. 97.4 % of the analyzed apps are free and the rest of the apps have a price range from $1,99 to $3,99.

The apps were also divided across 18 categories, as shown on the website [2]. The maturity rating of the apps, can be respectively ages 4+, 9+, 12+ or 17+. These age ratings are based on the content of the apps and shows if Vuforia is mostly used for apps with a low or high minimum age for use. Most of the apps (84.8 %) are suitable for persons of 4 years and older. The rest of the maturity ratings are almost equally divided.

The categories : Advertising, Apparel, Architecture, Art, Automotive, Education, Electronics, Politics, Publishing, Retail/Etail, Sports, Tourism and Toys which scored an average age maturity equal or lower than 5 were placed as less serious categories. The categories Entreprise, Entertainment, Food & Beverage,Gaming and Health which received an age maturity average higher than 5 were placed as serious categories. Figure 2 details the different categories with the less serious categories in green and serious categories in blue.

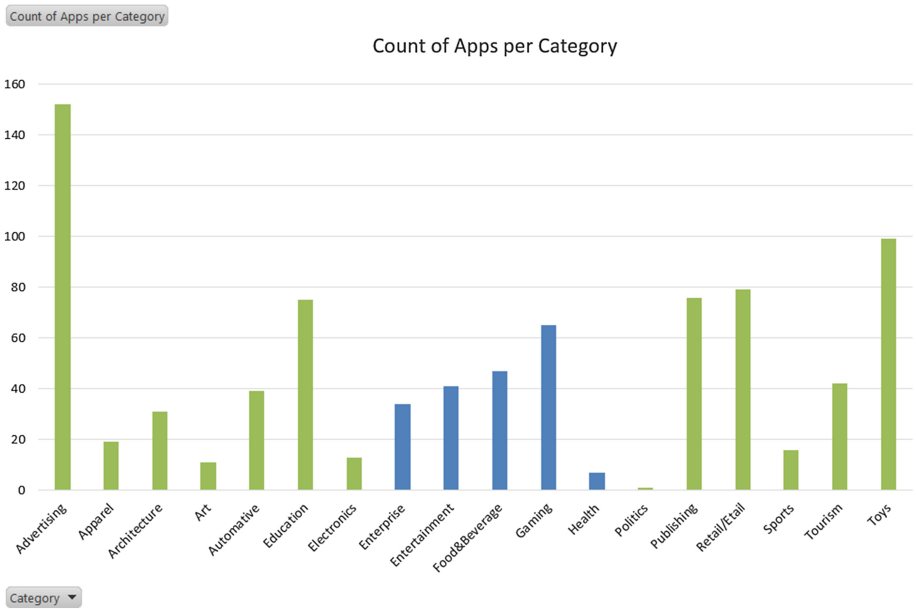

Fig. 2. Number of apps per category (Color figure online)

With the average age maturity of every category, a regression on the app categories could be performed, therefore 2 groups were conducted: Group 1 are the less serious apps and Group 2 are the serious apps. Three hypotheses have been conducted to measure the correlations between the ratings, maturity ratings and app categories.

– H1: Less serious categories get more ratings.

The Pearson correlation test gives us significance of 0,004 which means that we are not able to reject hypothesis H1. There is a correlation between the category of the apps and the number of ratings they get.

– H2: Apps with immature content get lower rates.

The test result from the Pearson correlation is 0,628 which is higher than the significance level so we have to reject H2.

– H3: Apps with mature content are paid over apps with immature content.

The correlation test on the third hypothesis shows us that the apps with mature content are not paid over apps with immature since the outcome is 0,939 on a significance level of 0,05.

3.2 The Software Network of Augmented Reality SDKs

The software components that are part of Vuforia could be interacting and connecting with other components outside Vuforia's own ecosystem like other AR SDKs, together forming the software network [6]. A comparison of several AR SDKs is made to find out where the other platforms of the software ecosystem are placed in the overall AR SDK market, and which one is the best to use for developers.

D. Amin and S. Govilkar [7] did an extensive comparison on the differences between AR SDKs. Metaio [8] has recently stopped selling their products and subscriptions because it was sold to Apple in 2015 [9]. It is not clear what Apple's plans are with the SDK therefore Metaio will not be taken into account in the comparison.

The first point in the comparison made by Amin & Govilkar [7] is based on the license type the mentioned companies use. As we can see in Table 1 only ARToolkit provides an open source license, and is also available for free as for commercial. The rest of the SDKs are available for free or can be bought as a commercial version.

Table 1. Comparison based on license type and supported platform [7]

AR SDK Type		Vuforia	Metaio	Wikitude	ARToolKit	D'Fusion	ARmedia
License	Open Source	✗	✗	✗	✓	✗	✗
	Free	✓	✓	✓	✓	✓	✓
	Commercial	✓	✓	✓	✓	✓	✓
	iOS	✗	✓	✗	✓	✓	✓
	Android	✓	✓	✓	✓	✓	✓
	Windows	✓	✓	✓	✓	✓	✓

The second point in the comparison is the platform which the SDKs support, the possibilities have been narrowed down to iOS, Android or Windows. Only Vuforia and Wikitude are an exception because their SDKs does not support iOS. The rest of the SDKs support every platform.

3.3 The Orchestrator: From Qualcomm to PTC

The first orchestrator of the Vuforia ecosystem was the company Qualcomm, founded in July 1985 in San Diego (U.S.), which focuses on a variety of industries. In an official statement on November 3rd Qualcomm presented the sale of Vuforia to PTC Inc. PTC is a global provider of technology platforms and solutions and is like Qualcomm also focusing on IoT, Smart Homes, and is deployed in 28,000 other businesses.

On the news page of PTC's website [10] they state that PTC commits to not only the continued growth of Vuforia technology, but also to the community, and the Vuforia ecosystem. According to Qualcomm, the current apps will remain

unchanged and developers will continue to have the same level of support from the Vuforia team [2]. PTC's plan is to combine Vuforia more with the IoT: *"Vuforia has also captured the attention of industry leaders who envision the potential for augmented reality to transform work."*

4 Discussion

4.1 The Developers Network and Applications

Within the research on the Vuforia SECO, the individual actors are the developers. According to Manikas and Hansen [6] it is important to look at the health of the individual actors because they influence the overall health of the ecosystem (p. 32)."*The active participation and engagement of actors brings value to the ecosystem, while the actor's robustness increases the probability that the actor exists and remains involved in the ecosystem activity in the future.*" This statement can be proved according to the findings of this study. With the 5 most active users we notice an important number of contributions in the forum with publications from 129 topics to 61 topics. These topics generate other responses from other actors in the ecosystem, making the network actors connecting between each other. As noticed that those top actors are active already for several years from 2010 up until now.

According to the data extracted the number of active developers posting in the forum is important with 4.803 developers, although the website states a bigger number the assumption is made that this number includes all the registered developers in the website.

The network of actors and their interaction within an ecosystem play an important role in the SECO health of Vuforia and any other platform [6]. As an addition to this, Manikas and Hansen state that the individual actor health can be weighted according to the role of the actor in the network. The active developers are more likely to make improved apps since they are more involved in the ecosystem. If the developers feel confident in posting articles and information on the developer portal, they will feel confident in the network. We have seen that the network of actors is quite large with 184289 users and 63353 posts.

This research looked into the apps of Vuforia, the categories, the customer ratings, the maturity ratings based on the content of each app and if it is a free or paid app. This is done to see if it is interesting for Vuforia to invest in apps with more mature content according to the number of ratings they get. This is also interesting for the developers since they know if their apps with the use of Vuforia make them successful or what kind of apps are most rated. The correlation tests in SPSS showed us that there is a correlation between categories and the customer rating, and between the app categories and the app ratings.

The conclusion from the first hypothesis is that less serious categories get more ratings. This could be because of the number of users per category. Another possible reason is because the less serious category contain more apps than the serious ones (98 apps in category toys against 6 apps in the category health).

The third hypothesis showed us that apps with more mature content are not paid over apps appropriate for users with a lower minimum age, this means that the apps with immature content can generate the same revenue as apps with mature content. The developers will not gain more money with apps that contain mature content and Vuforia does not really have to focus more on the developers that make more serious app.

We noticed that after the release note of a new component or new version of the SDK the publications about questions and tutorials on how to use them gets higher. The library prepares a mention of frequently asked questions followed by a detailed answer to it. Links to tutorials are provided to understand how to use some features of the SDK. Adding to it a whole page following step by step how to start a work space for beginners. All these subject are related effectively with all the details and videos that explain the use of the tool and how to fix some errors for example.

4.2 The Orchestrator: From Qualcomm to PTC

According to Syed and Jansen [11]: "*SECO orchestrators can develop strategies to keep a SECO vibrant and profitable for other organizations in the SECO*". Manikas and Hansen [6] refer to the orchestrator as the one that can monitor the health of the ecosystem and take measures to promote ecosystem health if necessary. To monitor the health, the orchestrator needs a good overview of the ecosystem and must consult effective measurements. In the case of PTC this can be hard in the beginning because Qualcomm has already build an ecosystem on its own. Additionally, the orchestrator can act by creating rules and processes for the actors, this is also a point where PTC has to put effort to keep the developers, which are part of the developer community, happy. The change of orchestrator is not yet really visible and might indicate that it will take some time to figure out which orchestrator will make/have made Vuforia a complete and successful ecosystem.

5 Conclusion

This research paper focused on the health of the Vuforia platform ecosystem and tried to answer the research question: **Can Vuforia improve its position in the market of AR platforms?** The analysis on the developers and developer network showed us that the actors of the ecosystem are well connected through the forum in the developer portal.

The network consists of a large number of developers and the active ones seemed to be active already for several years. For the complete ecosystem of Vuforia, the developer network does not need extra attention, but PTC should be aware of the possible changes it brings and should make sure that the developers stay well connected and content. The Vuforia platform is well accessible for developers and non-developers to gain information on the application and the ecosystem.

After analyzing the apps on Qualcomm's website not only a correlation between the categories of the apps and their rating was found but also between the app categories and the maturity ratings. Less serious categories seem to get higher ratings, this means that for the revenue of the company and its position in the market, the focus should be on these app categories. A reason might be that the apps in a less serious category are used for entertainment and are more fun to use in contrary to more serious apps. The actual reason of the outcome could be measured and studied in further research. Less serious apps do not get less or lower rates, and serious apps are not paid over less serious apps.

The comparison between AR SDKs in the software network showed us that no framework is the best and the choice of SDK depends on the choice of the developer. According to PTC, Vuforia is already the biggest player but Metaio has been bought by Apple and could rise to become big competition for Vuforia.

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