



# A precise view of big data based analysis on various parameters under the field of gaming analytics

R. Udaya Nirmala Mary \*, R. Nandhini

CSE, Karpagam College of Engineering, India

\*Corresponding author E-mail: [udaya.7it@gmail.com](mailto:udaya.7it@gmail.com)

## Abstract

Big data and analytics has brought revolutions in many of the fields. Gaming is one such field. Analytics is being implemented in games to classify the user and predict their behaviors. These techniques require some basic survey on gaming and analytics. This article is such an approach to game analytics focusing on its origin, causes, effects and machine learning techniques used in game analytics. This survey provides a better understanding about game analytics and the publications related to it.

**Keywords:** Big Data, Gaming, Machine Learning, SVM .

## 1. Introduction

Games find its origin from the board games. Board games are evolved from race games to the online games which we play today. It is a combination of both hardware and software. The hardware is the board or the components which we use for playing and software is the set of instructions which are followed. A change in the instruction leads to a new game. A game is considered alive if it is being played by everyone and it is dead if it is not played. A game lasts longer by inducing the player to continue playing and reach further levels[1]. Video games started its journey in 1961 with the invention of the game Spacewar by Steve Russell[2].

The motivations for each player differs for each game. Theories like self determination theory (SDT), player personality theory explains the player motivations. SDT predicts the motivations and says that a game must satisfy the psychological need of autonomy, competence and relatedness. Player personality theory explains about the interactions of players. Recent researches on massively multi-player online role playing game (MMORPG) had three factors having ten sub factors. The difference in player motives decide to which game is considered healthy and which leads to pathological or problematic game use[3].

The gamer is induced to play the games as there cannot be a shame and there is a victory. This decreases the stress in him as he may be subjected to shame while facing or playing in the real world rather than virtual. The gamer achieves glory when he ranks top in the game world and the game develops based on the ability of players[4].

Games has both positive and negative effects on the gamer. A game can be played to release the stress and pressure which is developed in the real environment and at the same time addiction to games causes more stress for the users to spend more time and to reach goals. They get farther from the real environment and live in virtual life. It has many health impacts which are discussed in upcoming sessions.

Nowadays games are into analytics. Regression techniques are used to predict the behavior of the users. The games are also ranked by using data from web search[5]. Moreover revenue of

gaming industries is increasing due to excessive online games played today.

## 2. Interest towards game

Games are played to release pressure and to kill the time. Interest is one of the factors which induces the gamer to play and spend time in it. The search details of people worldwide is collected and their interest towards the games are visualized. The interest of playing games online and downloading the games are compared. People show almost the same interest towards downloading games and playing online. Data for the last 2 years is obtained from Google trends [6] and visualized in Tableau which is shown in the figure 1.

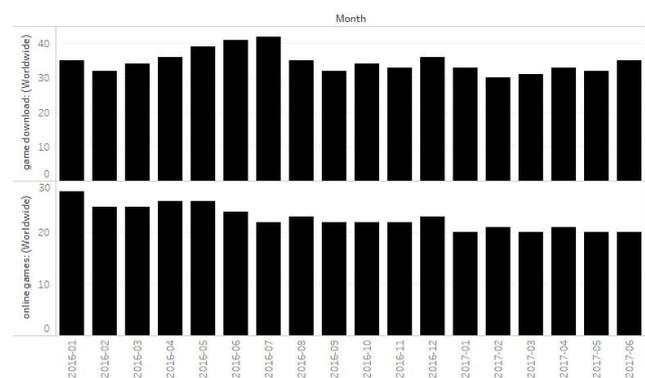
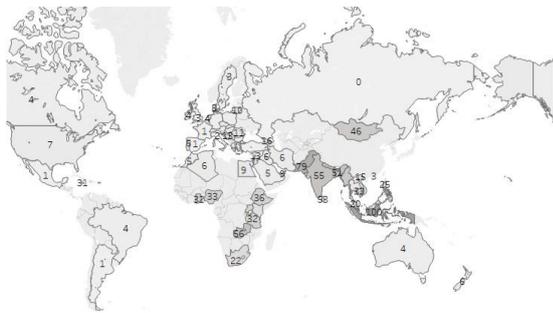


Fig. 1: Comparison of interest towards games

The above plot shows the interest of people towards downloading and playing online on a monthly basis and they are almost equal. Based on region the data is retrieved from Google trends [7] and visualized in Tableau. The geomap which is shown in the figure 2 shows the interest of people worldwide playing games by downloading it.



© OpenStreetMap contributors

**Fig.2:** Geomap showing interest of people towards downloading games

The above plot is done based on the data for the past five years(2012-2017). Results show that Pakistan people search for downloading games on a higher rate.

The data for searching online games in Google trends [8] is also collected and visualized in figure 3. This data consists of the number of web searches for online games for the past five years (2012-2017) worldwide and it is identified that Pakistan people shows greater interest towards online games.



© OpenStreetMap contributors

**Fig.3:** Geomap showing the interest of people in online game

### 2.1. Benefits of gaming:

When it comes to gaming it has special benefits. There exists some wrong perspective on gaming effects. Every thing has pros and cons. So gaming also have disadvantages. Its is better to take the positive side of it and consider them. Gaming helps to improve thinking ability outside the box. In a game, if one cannot complete a mission or level with the ways he uses currently, there rise a situation that he has to try a different strategy where some missions requires more than once of trying. When a game is being played based on his interest, the player is not disappointed by any of the situations. Instead if that is considered as a challenging task, then the player is hell-bent in finishing it. A Gamer have two alternative worlds , where one is actual and the other is the one which the player builds with his own creation. A game provides a positive feedback to the one who plays it and motivates the gamer to face the real world which makes him a better person. A new character can be born. There exists strong enough evidences that there are largely unexplored mental health benefits of gaming. In US 97% people spend at least an hour of their time in gaming. In past decade, the nature of gaming has been entirely changed. Four important aspects of benefits are taken into account. They are cognitive, motivational, emotional, and social[9].

The most popular stereotypes about the damage that the computer games may cause and their positive influence on a person are described. Video games has become a part of our world. The people are divided into divisions , certain people make a stronger connection with games within short period of time line . Where as there are only very few people who gives a thinking about what happens when they are overwhelmed with these games[10].

Video games initially chose magazines as portal for advertisement. Later game developers utilized every possible means to

advertise their product. They had to spend quite a fortune for it as it makes the first impression on the people. A separate team of guys are assigned for the making the game trailers. These guys learns every trends and work to their maximum effort to produce the best results. 2013 is like big break through for the gaming industries. In this year, various gaming consoles got introduced into the market and became a biggest hit. This again changed the time line and set different course for exploring new fields. 47.8 percent men played video games and talked about playing 36.7 percent of the time. When it is compared with women there is not much of a difference. It is more or less equal[11].

### 2.2. Preference of gaming machine:

Games can be played in various devices. The question is to which device is preferred the most? This changes according to the people's circumstances. Games too differ based on the device on which it is played. By playing games in different devices a player gains a special experience from it and then which one suits the player is decided. There are a lot of gaming devices to be chosen. The paper called "What Does a Gamer Look Like? Video Games, Advertising, and Diversity" describes that 89% select Xbox as their favorite device. The Xbox's joystick is designed comfortably to fit the user's hand. Every button is capable of enduring a several button press. It comes handy and portable. When it is played in a bigger screen ,it provides massive scale entertainment and adventure[11].

### 2.3. Division of peoples:

The younger group of people have tried at least one game in each category to know what the game might have and then decide which category caught their attention and interest. Approximately 80.53% of younger group intent to play more. 54.7% of the older people prefer to play alone. They expect more space, that's why they choose gaming in the first place. In a survey it is indicated that when adults play multi-player open world games, it provides a better team work between them. The teens , because of high curiosity in the game , there is possibility of messing things up. Since maturity is still in developing process for them , it becomes a bit difficult for them to adjust in the environment.

It is understood that after a certain period of age , change of taste in a person is more likely to remain the same. So when a person plays a game category for more than 5 years , then in near future he would play the same category. The aging process itself may limit the individuals' capacity to play games they previously enjoyed. It leads them to seek out slower paced genres such as puzzle games[12].

### 2.4. Anticipation of games:

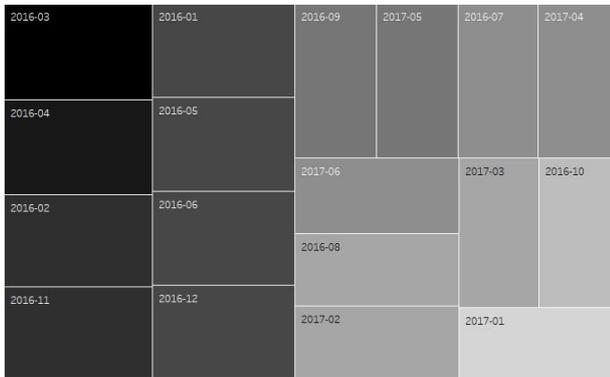
The games must be easy to learn and play and also it must be challenging. The game's story line act as one of the major part in the game features. The graphics in gaming are the first one which spark the positive feeds. If the graphics in a game makes a person to be stunned , almost they made it though. When a player finds the virtual world to be extraordinarily attractive and colorful , his curiosity increases on the game. The open world games are expected to contain an enormous environment to explore and play. Creating interesting sub missions in the game would provide freedom for the players to spend time apart from the main story line. This increases the duration of time for a person to complete the game. The open world game team ups leads to more groups to fit in a game and enjoy as a team. In process of creating new games, the game developers try an entirely different line and chance of its failure is high because for gaming there are certain standards that have to be met.The legendary game company like ubisoft build their great games in a pattern.They have got bigger picture to process and start working by dividing their jobs.The person who works on a specific task has to learn everything from the scratch to provide detailed analysis of that part. Even the story line that they choose will be based on true events. The games must be crazy

enough that the player find it hard for removing gaming experience from his memory[12].

## 2.5. Excessive gaming:

Too much of anything is danger. No matter how good or bad it might be. In gaming it is easy for people to get carried away. It is not their fault because there are so much on their plate and many things going on in their life, they get exhausted and fall in the depression pool so that they are unable to find a way out. In their darkness, the distraction like gaming is like tiny bright shining light. They hold on to that one thing and give themselves into it. Instead of fighting the real in the real battlefield, they select the alternate one. It may be good in certain extent but the person has to come back with what he had learned from it. When they are at the edge of obsession, there will be only few steps for the free fall.

Games' effects are destructive. The list of few destruction which games have caused among the people are (i)Players sometimes lose sleep because of the time they spend in playing console games, (ii)they sometimes skip their meals or delay in-take of food because they are busy playing, (iii)they have had conflicts with their partner or parents over the time they spend in games, (iv)they have lost contact with some friends because they rather spend time on games, (v)their school/job performance has suffered because of the time they spend on games[13].



The interest of people towards addictive games for the last 2 years has been collected from Google trends [14] and visualized in tableau. Almost same frequency of searches have been carried out in each month.

## 2.6. Gaming's part in stress:

For every thing, there needed some sort of motivation trigger to be pulled in order to work things passionately. Gaming is a stress buster when it is used effectively. When people find something interesting, they will develop a habit in consecutive intervals which eventually leads to obsession. People are stressed out due to various reasons in their life. After a long day, they need something to take their mind off. So to do that they choose gaming for it. Gaming helps people to enter a different world every time and play with any character they decide to play with. There is no age limit for gaming. According to their mind set, people can choose games in the wide range of games available. Playing games release stress up to 4.9%. Gaming also helps people to make connection with one another and share similar vibes. Where two person play the same game and there is a friend request option available. When these requests are accepted, they chat with one another and share their common interest. If these things work, there builds a bond. When this happens to a group of people with same flows and there forms a team. People find hard to build relationships. People aren't the same. Even though there are billions of people around the world, to find a person who shares the same weirdness are difficult. So these gaming platforms, in spite of stress busters they also act as a connecting platform.

The game industries create the games with amazing graphics and story line. People get inspired by these events and try to do

something better with more confidence and interest. It even gives an idea in choosing their career paths. There is also a possibility that violent games turn out into bad endings to certain persons and not all. But that is the worst case scenario. There also exists a fact that boys prefer violent games than others. It may be true, what they actually do is that they transfer their anger feeling which they obtained in real world into the games and deal with it in such an environment.

A player can't express his anger towards a person who caused it explicitly as it leads to a totally different set of problems. That anger which has been created must be dealt with a different strategy that includes no consequences. So they imagine that person or something on what they are angry as a game character enemy and try to kill it or do something and compensate that anger. By this way anger problems are solved effectively with different approach[15].

## 2.7. Health effects:

Games also have positive effects on human health. Researches show that they improve the laparoscopic skills of the students. Teens with greater experience in games have more skills. The greater the gaming experience, lesser is the errors produced. Students with high gaming experience were able to attain the proficiency quicker after training compared to others. The skills were tested using simulators and the results were obtained[16].

Samples from Greek school children were collected and analyzed. The factors which were considered are their food habits, snacks, physical activity, presence of TV and video games and their parents' activities. The results showed that video games reduce their physical activity leading to over weight (OW) and obesity (OB)[17]. A report from the data collected from students of South Asian countries also resulted that children who play prolonged video games was affected with obesity[18]. A study of children across 12 countries showed that a child with at least one electronic media equipment (TV or play equipment) reported low moderate to vigorous intensity physical activity (MVPA) than the children with frequent physical activity. MVPA differed for different countries[19]. A study also reported that family intervention reduced the sedentary behavior of the children [20].

Survey from the Chinese adolescents infer the facts that playing violent video games increases the tolerance level towards violence, reduced empathy and higher aggression. The exposure of people towards games are indirectly related to their behavior. More responses are towards the attitude than on behavior. These conclusions are got based on two theories. Desensitization theory says that when a child or adolescent is exposed to violence through video games for a long time their sensitivity towards it is reduced so that they can tolerate those situations [21]. Next is the culture, in most of the countries random violence is restricted. Children are not exposed to aggression. Hence it is reported that violent games has greater effects on attitude than on behavior. However, a gamer who is exposed to violent games shows more aggression than others. A comparison between different countries' gamer population is also made. 78.1% of Chinese adolescents play and they prefer online games [22].

A survey was made by splitting the children into groups and making them to play a violent game or a non violent game. The results showed that the children who played violent games showed more aggression than who played non violent games [23]. It is also found that boys who often play games shows more aggression than girls [24].

Students were tested for their spatial cognitive skills (ability to visualize two dimensional and three dimensional figures), visualization and their eye hand co-ordination. Students who play games developed more spatial skills and eye hand co-ordination irrespective of their ages [25].

3D video games training improves the memory functions. Traumatic brain injury (TBI) occurs as a result of mechanical injuries in head. This results in amnesia and abnormal behaviors. They suffer by not following daily routine. The TBI patients were made

to attend cognitive rehabilitation program so that they were allowed to learn strategies of games[26]. Post-training showed improvements in their skills. Patients were able to carry out their daily routine. The players learn the strategy to win and memory connections are enhanced. Hence these treatments are done for people affected with autism(unable to communicate and interact),stress disorder and anxiety.

## 2.8. Educational games:

The main purpose of the educational games is to develop the students' levels in the learning. The educational games improves the skills of thinking. The game developers will concentrate mainly on the students and develops a game such that a student plays for a longer time as well as improves his learning process.

The authors Per Backlund, Maurice Hendri in their article "Educational Games – Are They Worth The Effort?, A literature survey of the effectiveness of serious games"[27] analyzed educational games in the field of the education and made a survey on the previous works done in the filed of the serious games.

"Computer Gaming and Interactive Simulations for Learning: A Meta-Analysis"[28] deals with meta-analysis on multiple criteria related to the educational fields. Games are also considered as one of the criteria. As per the survey both the educational games and entertainment games can be used to increases the solving skills and thinking capabilities of the students.

## 2.9. Big data analytics:

The new era of Analytics has emerged in the last few years. Analytics involves collection of data, cleaning ,analyzing and visualization to retrieve a specific information. Big data and its analytics comprises of techniques to analyze data which are complex in the size equal to and greater than terabytes. Analytics find its applications in almost all the domains nowadays. One of the fields is business intelligence. In [29], they have combined business intelligence and analytics as a single term since the field of analytics offer a new path to business intelligence.

Simon after knowing the efficiency of big data and analytics quoted that "a wealth of information creates a poverty of attention"[30].

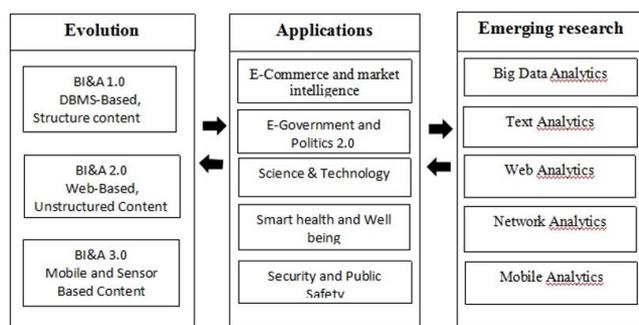


Fig. 4: BI&A Overview: Evolution, Applications and Emerging Research

## 2.10. Different types of machine learning algorithms used in game analytics:

In game analytics various machine learning algorithms has been used based upon the application. "Google's self-driving cars and robots get a lot of press, but the company's real future is in machine learning, the technology that enables computers to get smarter and more personal", these words are uttered by Eric Schmidt (Google Chairman). Machine learning can be simply stated that for an instance if the user gives the slope equation  $y=mx+c$  and provided the inputs  $m$  and  $c$ ,the algorithm trains and tunes itself to calculate  $x$  and  $y$ . The following survey gives the clear vision of frequently used algorithms which has being used in copious game analysis. The clustering techniques also plays an important role in analysis which is used to sample a large set of data and visualize easily. The following are the frequently used

machine learning algorithms-Linear-Regression, Logistic-Regression, Decision Tree, SVM, Naive Bayes, KNN, K-Means, Random Forest dimensionality Reduction Algorithms, Gradient Boost & Adaboost. From these, frequently used machine algorithms in game analysis are k-means, SVM(Support Vector Machine), Navie Bayers.

## 2.11. Support vector machine(SVM):

For the survey of the game analysis we can take the work "On Prophesying Online Gamer Departure"[32] done by authors Pin-Yun Tarn<sup>1</sup>, Kuan-Ta Chen<sup>2</sup>, and Polly Huang<sup>1</sup>. The theme of this paper is to predict the gamer how long he stays in a platform of the online games and why the gamer quits. The means to increase the revenue of game developers are considered. Random traces from the ShenZhou Online [31] which is a MMORPG in Taiwan are collected. Classification of the gamer based on the involvement in games and time which they spend on playing the game and playing density is done. SVM ( support vector machine) is used as the classifier.

SVM is an algorithm which is used to plot the data item of a particular co-ordinate in the  $n$  dimensional space where  $n$  refers to the number of the feature. For an instance when two features of a person (length of the hair ,height) are considered to describe SVM. A plot of the two co-ordinates (these co-ordinates are called Support Vectors [33]) on the 2 dimensional space is done. After implementing SVM a line splits the two different co-ordinate into two groups and this line is decided based on equal distance between the two classification. Based on that line new data are classified.

In [32], SVM is used to classify and predict the gamer who leaves the games which gives a suggestion to the game developers based on the two features - "sudden out" and "fade out".

## 2.12. K-means algorithm:

In Clustering Game Behavior Data [34],the authors Christian Bauckhage, Member, IEEE, Anders Drachen, Member, IEEE, and Rafet Sifa made a review and analysis of the clustering techniques in the mining behavioral data from games. They used "k-means" clustering algorithm for game analysis.

"k-means" falls under the category of unsupervised. It is easy to classify because the procedural flow of the k-means is easy. The classification is done based on the data set clusters( assume  $k$  is the cluster)[35]. Data points inside a cluster are homogeneous and heterogeneous to peer groups. The k-means shape is similar like ink blots. The blots refers to the classification of the data set.

How K-means forms cluster[35]

- Centroids are the  $k$  number points picked by the K-means.
- Based on the closest centroid each data point forms a cluster (ie)  $k$  cluster
- Based on the existing cluster members the centroid of the each cluster is found.
- Thus new centroids are formed.
- Repeat the step ii and iii as new centroids are formed.
- Again find the shortest distance between each data point from new centroids.
- This process is repeated till encounter occurs.

## 2.13. Naive Bayes:

The work of Brent Harrison and David L. Roberts in the paper "When Players Quit (Playing Scrabble)"[34], shows the prediction why the players are quitting the game Scrabble. In [34],data set is created based on each feature deviation from a expected value. Transformation feature technique is being used to create data sets. By using this data set they predict the gamer probability of quitting by Naive Bayes model.

The Naive Bayes works under the principle of the "Bayes theorem" and an independent assumption between the predictors are made. A particular feature in a class is not compared with any other feature in the class. For an instance a fruit may considered as

an orange if it is orange in color ,round in shape and diameter to be 4cm. Naive Bayes would consider the fruit as an orange if it is orange in color alone and does not check for shape and diameter. It is not dependent on other features. Hence it considers all the properties individually even though all features is dependent on each other. Using the Bayes theorem posterior probability  $P(c|x)$  from  $P(c)$ ,  $P(x)$  and  $P(x|c)$  can be calculated from the below equation 1[36].

$$p(c|x) = (p(x|c)p(c)) / p(x) \quad (1)$$

$$[p(c|x) = p(c|x) = p(x1|c) * p(x2|c) * ..... * p(xn|c) * p(c)] \quad (2)$$

Here,

$P(c|x)$  is the posterior probability of class (target) given predictor (attribute).

$P(c)$  is the prior probability of class.

$P(x|c)$  is the likelihood which is the probability of predictor given class.

$P(x)$  is the prior probability of predictor.

### 2.14. Adaptive Regression:

An article by BenG.Weber,Michael John,Michael Mateas,Arnab Jhala ("*Modeling Player Retention in Madden NFL 11*") the game play of the specific features of the specific players are identified. The player retention in improvement of the game NFL 11[37] is identified. Adaptive regression is similar to the linear regression but it is step by process. They are simple then the random forest and neural networks[38].

## 3. Conclusion

People are projected with different angles of view in gaming . The exact thing what is happening in gaming and analytics has been discussed. The origin, cause, effect, benefits and disadvantages of gaming is identified. This would help to predict what a gamer might look like or how he would behave to certain circumstance. Research in several aspect of gaming papers is carried out. The choices of users' game download options and searches have made into graphical representation with the help of tableau software, which is especially a visualization tool. An insight of how the machine learning algorithms fits in this gaming is given. When a suitable algorithm combines with the spirit of a game it is practically magic. Predicting the user behaviors would help to increase the complexity of the game. These factors provide insight into the field and help game developers to build a better game and make the world a better place to live.

## References

- [1] Evolution for games Cosimo Cardellicchio CNR ICCOM c/o Dipartimento di Chimica Universit  di Bari
- [2] Video games production networks: value capture, power relations and embeddedness Jennifer John.
- [3] Individual differences in motives, preferences, and pathology in video games: the gaming attitudes, motives, and experiences scales (GAMES) Joseph Hilgard, Christopher R. Engelhardt, and Bruce D. Bartholow.
- [4] Glory and shame: powerful psychology in multiplayer online games Baron J.
- [5] Nowcasting Mobile Games Ranking Using Web Search Query Data Yoones A. Sekhvat.
- [6] The benefits of playing video games. Granic, Isabela; Lobel, Adam; Engels, Rutger C. M. E.
- [7] Video Games Benefits *Dmytro Kozak*.
- [8] What Does a Gamer Look Like? Video Games, Advertising, and Diversity Shira Chess, Nathaniel J. Evans, Joyya JaDawn Baines.
- [9] The moderating role of psychosocial wellbeing on the relationship between escapism and excessive online gaming Daniel Kardefelt-Winther.
- [10] Friends, fun, frustration and fantasy: Child motivations for video game play Christopher J. Ferguson Cheryl K. Olson.

- [11] Hierarchical analysis of dietary, lifestyle and family environment risk factors for childhood obesity: the GRECO study P Farajian, D B Panagiotakos, G Risvas, O Malisova and A Zampelas.
- [12] Household-level correlates of children's physical activity levels in and across 12 countries Harrington DM, Gillison F, Broyles ST, Chaput JP, Fogelholm M, Hu G, Kuriyan R, Kurpad A, LeBlanc AG, Maher C, Maia J, Matsudo V, Olds T, Onywera V, Sarmiento OL, Standage M, Tremblay MS, Tudor-Locke C, Zhao P, Katzmarzyk PT; ISCOLE Research Group.
- [13] Family-based interventions for reducing sedentary time in youth: a systematic review of randomized controlled trials Marsh S<sup>1</sup>, Foley LS, Wilks DC, Maddison R.
- [14] The Effects of Long-Term Exposure to Violent and Sexually Degrading Depictions of Women By Linz, Daniel G.; Donnerstein, Edward; Penrod, Steven.
- [15] Effects of Playing Violent Videogames on Chinese Adolescents' Pro-Violence Attitudes, Attitudes Toward Others, and Aggressive Behavior RAN WEI, Ph.D.
- [16] Effects of Playing Videogames on Children's Aggressive and Other Behaviors.
- [17] Nobuko Ihori ,Akira Sakamoto ,Akiko Shibuya ,Shintaro Yukawa
- [18] VIDEOGAMES, AGGRESSION, AND SELF-ESTEEM: A SURVEY : Fling, S.; Smith, L.; Rodriguez, T.; Thornton, D.; Atkins, E.; Nixon, K.
- [19] Videogames and spatial skills: An exploratory study Diana Gagnon.
- [20] Video game play changes spatial and verbal memory: rehabilitation of a single case with traumatic brain injury Marcella Caglio, Luca Latini-Corazzini, Federico D'agata, Franco Cauda, Katuscia, Sacco, Silvia Monteverdi, Marina Zettin, Sergio Duca Giuliano Geminiani.
- [21] Educational Games – Are They Worth The Effort? A literature survey of the effectiveness of serious games Per Backlund Maurice Hendri.
- [22] 'Computer gaming and interactive simulations for learning: A meta-analysis'.
- [23] J. J. Vogel, D. S. Vogel, J. Cannon-Bowers, C. A. Bowers, K. Muse, and M. Wright.
- [24] Business intelligence and analytics: from big data to big impact Hsinchun Chen, Roger H. L. Chiang, Carl H. Lindner, Veda C. Storey, J. Mack .
- [25] Computers, Communication, and the Public Interest, Baltimore. Simon.
- [26] On Prophesying Online Gamer Departure Pin-Yun Tarng<sup>1</sup>, Kuan-Ta Chen<sup>2</sup>, and Polly Huang.
- [27] A simple SVM algorithm S.V.M. Vishwanathan, M. Narasimha Murty.
- [28] Clustering Game Behavior Data Christian Bauckhage, Member, IEEE, Anders Drachen, Member, IEEE, and Rafet Sifa.
- [29] When Players Quit (Playing Scrabble), Brent Harrison and David L. Roberts North Carolina State University Raleigh, North Carolina 27606.
- [30] Constrained K-means Clustering with Background Knowledge Kiri Wagstaff, Claire Cardie, Seth Rogers, Stefan Schroedl.
- [31] Learning an Optimal Naive Bayes Classifier M. Martinez-Arroyo, L.E. Sucar.
- [32] Modeling Player Retention in Madden NFL 11, Ben G. Weber, Michael John, Michael Mateas, Arnab Jhala.
- [33] Multivariate Adaptive Regression Splines (MARS) Puneet Bansal, Jackson Salling.
- [34] The Research and Analysis on the Situation of College Students' On-line Games, Jielei Jiang and Jianming Fu.