Cloud Computing for brain segmentation – a perspective from the technology and evaluations

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***Abstract*— This paper examines the potential benefits that Cloud Computing can bring to the area of brain segmentation with regard to satisfactory technical and user evaluations. It explains eleven APIs associated with each brain segment, as well as the process of capturing data in regard to each segment. Functionality and experiments associated with each API are discussed. Dancing is chosen because data related to fast and skilled movements can be captured more easily. The results captured for each brain segment are discussed and used to explain why some segments are more active in dancing. With an emphasis in testing to ensure a high quality of data analysis and visualization, eleven Cloud APIs can produce results quickly and accurately. The first evaluation is the use of brain segmentations developed for Medical Cloud Computing Education (MCCE). Results of analysis confirm that Cloud Computing can offer a 20 % improvement in learning satisfaction. The second evaluation is focused on recapturing a lost skill. Results confirm that volunteers have their heartbeat, blood pressure, emotion, body co-ordination and vision at their peak as demonstrated by Cloud APIs in numerical analysis and visualization. Benefits of using Cloud brain segmentation technology are presented. The use of Cloud Computing can make positive impacts to healthcare informatics, education and cost reduction.**

Keywords*— *Healthcare Cloud; brain segmentation technology by Cloud Computing; Medical Cloud Computing Education.

I. INTRODUCTION

Cloud Computing is reported to offer added values for organizational adoption in service computing and IT service management, where both Education and Healthcare sectors have demonstrated proof-of-concepts for delivering the next generations of scientific research, business models and education [1-9]. Healthcare informatics plays a strategic role in the UK National Health Service (NHS) to improve the level of healthcare services and the quality of education and research. These NHS IT initiatives include Cloud Computing, which demonstrates that scientific work can be enhanced; collaboration can be improved and IT services can be delivered. Fusion between healthcare, education and Cloud Computing can provide greater benefits to scientists, medical students and healthcare staff and successful fusion becomes increasingly important in modern healthcare development [4, 10, 11]. Hence, more universities have used Cloud Computing for education and research with case studies supported by NHS, University of Oxford and King's College London (KCL) [4, 9, 12]. There are interests to develop medical Cloud Computing including brain segmentation [13], which is the automatic assignment of neuro anatomical labels to portions of a brain image. Cloud Computing for medical services is aimed to offer inter-disciplinary collaboration and investigation [13].

To ensure successful delivery of this collaborative project, achieving an overall balance in key factors such as technology, users and funding is important. In other words, the technical implementation is not the only factor to determine the success of the project. Other factors involved with user and funding are required to determine the overall success of the project delivery based on stakeholders' requirements. The proposed solution should fit for the purpose of technical, user and funding requirements. People who use and evaluate the system can offer feedback and advice for continuous improvements.

The advancement in technologies is a driving force to blend with medical education and research [10, 13]. Together with improvements in learning strategies, Cloud Computing technologies can influence the way medical education and research can move forward [13-15]. To fulfill this long-term vision, this paper presents an innovative approach for blending both medical education and research, where brain segmentation is a case study to illustrate its positive impacts. The objective is to study how human brain responds while recapturing a skill that was learned two years ago. The research was conducted in a motivated and interactive environment to study the positive impacts offered by Cloud computing. Data collections for volunteers are conducted and analyzed for discussions. This paper focuses on the overall success of managing and adopting private Cloud applications for medicine. The breakdown of this paper is as follows. Section 2 describes the structure of human brain and explains the importance to understand this prior discussing Cloud Computing technologies and evaluation. Section 3 outlines the software and hardware technology required by brain segmentation and its experiments. Section 4 presents Cloud Computing system design and equipment used for preliminary experiments and approaches with regard to brain segmentation. Section 5 resents the results of actual experiments in the form of brain segmentation visualization. Section 6 presents the user evaluation and their statistical results. Section 7 describes the scientific evaluations and explains how steps and results can be reproduced. Section 8 presents four related topics for discussions. Section 9 sums up a conclusion and future work.

II. STRUCTURE OF THE BRAIN

Understanding structures and functions of the human brain is useful to see the connections between brain segmentation and Cloud Computing. The structure of the human brain is in Figure 1 as follows.

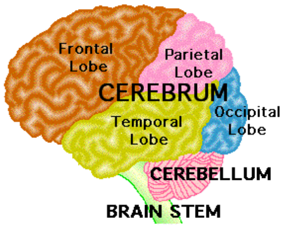

Figure 1: The simplified structure of the human brain

The structure and function of the human brain are explained as follows:

- Frontal Lobe: It controls behaviors, intelligence, memory (mainly short term) and movement.
- Parietal Lobe: It controls intelligence, language, reading and sensation.
- Temporal lobe: it controls behavior, hearing, storing new memory, speech and vision.
- Occipital Lobe: it processes human vision.
- Cerebellum: It controls balance and co-ordination.
- Brain stem: It controls blood pressure, breathing, consciousness, heartbeat and swallowing.

Each part of the human brain has its own functions and roles. Although some parts have overlapped functions, they have specific roles and responsibility for the human body. One example is memory, where frontal lobe is responsible for short term memory and temporal lobe is responsible for storing new memory. Long term memory will be stored in the inner layers of the frontal lobe.

A. *How does this relate to our study?*

Activities in our human brain are reflected in our learning. There are several research questions to explore, including the relationship between intelligence and brain activities; how learning can stimulate our brain and vice versa; how to develop each learner's potential through learning; how to maximize learning while understanding neuroscience more [16, 17, 18]. This motivates us to have a more established link between learning and brain science. While taking up new skills, our brain cells react differently, which is reflected as follows. Some people can learn a new skill quickly and also remembers it for a long time. Some people need more time to learn a new skill, and also have a high tendency to lose the skill if it is not practiced for some time. The majority of people need a while to learn a new skill and can still retain their skill for a difference of time (dependent on individuals). There are researchers who interpret that all these observations are due to the direct link between intelligence and memory. Those with high Intelligence Quotient (IQ) can learn faster and remember longer [18, 19, 20]. Some researchers disagree and argue that this is towards the attitudes of learning that affect the activities of the brain [16, 17, 21]. Although this question is not a classic "chicken and egg", it is important that scientists and educationist understand how people learn and how our brain cells react, and understand brain activities in the process of learning.

B. *Movement for capturing brain activities*

It is more challenging to record brain activities for a sedative activity such as reading, because it takes more time and it needs more sophisticated equipment to collect data. On the other hand, it is much easier to record brain activities that involve volunteers with rapid physical movement, which increase heart beat and blood pressure. Micro-sensors are able to detect changes in human heart beat and blood pressure easily. In this way, brain waves and associated activities can be collected more easily than a sedative activity that requires a high level of concentration for some time.

Dancing is chosen as it involves with rapid but sophisticated movement, and lots of movements can produce sufficient data for brain activities in different parts of the brain. Two groups of volunteers with eight in each group took part the study. Each of them attached a "brain-wave detection" device while taking part in dancing. Brain waves were recorded and sent to a private cloud which stored all the data and analyzed them. Cloud Application Programming Interfaces (APIs) are used to process and analyze data and present volunteers' brain activities (as a collective result) on brain segmentation. Details will be presented in Section 4.

III. THE BACKGROUND TECHNOLOGY

This section describes the software and hardware technology required for brain segmentation, and explains how they can be used during experiments to obtain data for computational analysis. Brain signals travel at the speed of light in the electrical waves. The term electroencephalography (EEG) is used to describe the recording of electrical activity along the scalp to understand how the human brain processes information based on the activities involved with the volunteers or patients. This often requires the highly-customized "brainwave device" based on the senor technology attached to volunteers to capture and process the data.

A. *The hardware technology*

The brainwave device uses twenty one extensions of micro sensors, and each extension can be attached to each volunteer during the experiment. Under each extension, the technology has a micro sensor attached to it, which can detect the brain activities based on the intensity of electrical signals in the brain. To illustrate all hardware technology, Figure 2 shows the brainwave device on loan, an equivalent version of a wireless EGG, which removes the need to attach to each volunteer to record brainwave data.

Figure 2: The brainwave device

Figure 3 shows the system architecture and briefly explains how the sensor technology works in regard to its deployment and its scanning images. Data collected by each micro sensor are sent to the "Receiver" as a gateway for recording, transmission and noise (outliers or signals not corresponding to brainwave reading) filtering. The Receiver is the official recording, storage and pre-processing of the collected data. The filtered data can be used for recording and processing before the action of Cloud APIs. Spikes are referred as the high intensity of the received signals and are commonly seen in the Receiver. Spikes can determine the level of the intensity of each brain segment during the experiments. There are more spikes, it means that the corresponding brain segment can provide a high level of the intensity. While this technology is useful to identify the intensity of the brain activities, additional software such as the Cloud APIs need to be in place to ensure the smooth process of data processing and analysis.

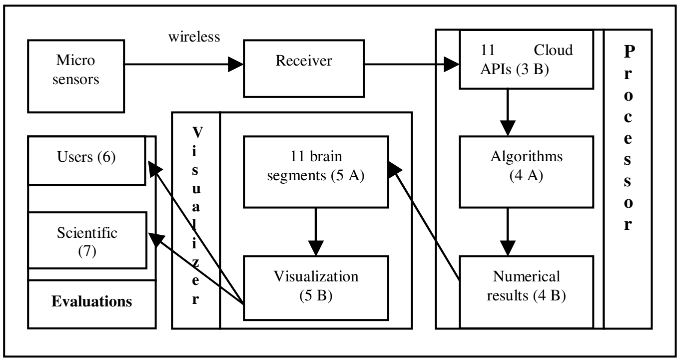

Figure 3: How the sensor technology works in regard to its deployment and its scanning images.

Figure 3 shows the process flow and the steps involved in this scientific project. After the filtered data is passed onto the "Processor", three steps are involved. First, eleven Cloud APIs in Section 3B are used to process the data collected by their respective microprocessors. Each API uses the algorithm with four steps described in Section 4A to process the data. The outcome of the data processing is presented as a numeric number described in Section 4B, where the numerical values represent the intensity of the brain activities. All numerical values are stored in their respective brain segment presented in Section 5A in the "Visualizer", which aims to present data as visualization with the detail discussed in Section 5B. Since user evaluations are important to determine the success of the project delivery, two types of evaluations have been undertaken. The first type includes the user evaluation that uses the adapted version of this brain segmentation (Medical Cloud Computing Education, MCCE) to study their learning satisfaction before and after using the MCCE discussed in Section 6. The second evaluation is focused on the scientific evaluation to understand how people can react while recapturing their skills presented in Section 7. Results and discussions presented in this paper can conclude the overall success of project delivery.

B. System Design and Development of Cloud APIs

Application Programming Interfaces (APIs) are used in Cloud applications with the following advantages. First, scientific complexity, such as numerous mathematical formulas associated with neuroscience need not to be presented up front, and this can improve the usability and interactions between researchers and volunteers during the experiments. Researches need not always process data or fix operational problems (such as system administration issues, or restart of software programs) during experiments. Second, APIs only needs to be presented with an interface that can receive data, process data and present data, including both numeric results and visualization. This can reduce the time to perform additional computational work during experiments. Up to twenty two extensions of micro sensors can be used, each pair of Cloud API can be used and measured by two micro sensors, because one micro sensor measures the data on a particular segment of the left brain and the other measure and collect data on the same segment on the right brain. The only exception is OccipitalLobe**,** whereby the mean values of the collected data can be the final value of the collected datasets. The value of 0 is the lowest and the value of 1 is the highest. There are eleven Cloud APIs described as follows.

- **UpperFrontLobe** – This API is to read the data from "brainwave device" attached to each volunteer, and it is wirelessly connected to the nearest private cloud server (wireless speed: 100 Mbps). The APIs connected to the device record the quantity and intensity of data. This API will compute a numeric number, as 0.000 as the lowest and 1.000 as the highest. If 1.000 is presented, the entire upper region of the frontal lobe of the human brain will be filled with visualization, which represents the overall activities of brain cells.
- **LowerFrontLobe** – Similar to above, except it is responsible for the lower front lobe.
- **UpperParietalLobe** – Same as above, except it is responsible for the upper parietal lobe.
- **LowerParietalLobe** – Same as above, except it is responsible for the lower parietal lobe.
- **OccipitalLobe** – There is only one API for Occipital Lobe as it is mainly dealing with human vision.
- **LeftTemporalLobe** – The functionality is the same as the first four APIs, except it is for left side of Temporal Lobe. Due to the structural difference, Temporal Lobe is divided into the left and right for APIs.
- **RightTemporalLobe** – Same as above, except it is for right side of Temporal Lobe.
- **LeftCerebellum** – Same as above, except it is for left side of Cerebellum.
- **RightCerebellum** – Same as above, except it is for right side of Cerebellum.

- **UpperBrainStem** – The functionality is the same as the previous APIs, except it is for the upper side of Brain Stem.
- **LowerBrainStem** – Same as above, except it is for the lower side of Brain Stem.

The "Processor" is connected to the private cloud platform based on high performance Cloud processing powers and algorithms. This can ensure that calculations can be executed within seconds by the use of computational resources and software algorithms to optimize the performance of data processing and analysis. Section 4 will introduce more about the algorithms used.

IV. CLOUD SEGMENTATION – SYSTEM DESIGNS AND PRELIMINARY EXPERIMENTS

This section describes the contributions from Cloud Computing for this project. Since eleven Cloud APIs have been introduced, a good algorithm is required to understand and interpret all these data. Descriptions in this section include Cloud Computing algorithm and approaches and preliminary work before the actual experiments are provided.

A. *Algorithms involved*

Each Cloud API has four common funcitons: read, process, update and visualize. All steps take place in sequential ways explained as follows:

- **read** (data) – This function reads all numerical data from brainwave device.
- **process** (data) - This function processes the data from the read operation. Collected data is recorded as datasets, which can be varied dependent on the quantity of the input data.
- **update** (data) – This function update all the data values for read (data) and process (data).
- **visualize** (data) – this function represents the numerical values in the phase of process (data). The intensity of each brain segment is represented by the numerical values collected and calculated.

The term dataset is to describe each set of collected values for read, process, update and visualize procedures. Each dataset contains a row of all the information associated with these four procedures. This needs a model to process and interpret the data before data analysis can take place.

All the datasets are read and processed by the use of Organizational Sustainability Modeling (OSM), which is designed to process and analyze big data [7, 13]. OSM is particularly useful to process large-scale data processing and interpretation, and is able to complete processing within seconds. OSM can provide up to 99.99% of accuracy and quality of the data analysis. The detail will not be presented in the next version of this paper which has a technical focus. Additionally, this paper aims to present the overall success of using and adopting Cloud solutions for medicine rather than presenting an in-depth algorithm and system implementation.

In summary, OSM can process datasets efficiently and quickly. For example, if each brainwave device had collected 500 datasets, OSM read all values and sums them, average them out (normally with an averaging ratio of 1:5), and displays the results. All the collected data received multiple of 5 of datasets, and can go up to 10,000 datasets verified during the testing phase. For the purpose of the experiments, 4,000 datasets were collected and analyzed, with an averaging ratio of 10. Matrix A contains all collected datasets. An example of code can be presented in Table 1as follows.

Table 1: Average execution time for different Cloud APIs

```
For (i==0; i<=400; i++)  // 4000 divides 10 is equal to 400
  read (Matrix A);
  process (Matrix A);
  update (Matrix A);
  visualize (Matrix A);
end;
```

B. *Hypothesis*

Based on literature review [16-21], a hypothesis is set.

H1: When people are involved in dance and physical movement, the lower parts of the brain are more active. This means that LeftTemporalLobe, RightTemporalLobe, LeftCerebellum, RightCerebellum, UpperBrainStem and LowerBrainStem should have the following characteristics based on experiments:

1) Shorter execution time to complete data processing;
2) Brainwaves receive higher numerical values, corresponding to the fact that they are more active than the upper brain segments.

C. *Preliminary work for testing*

Before investigating the brain cell activities in brain segmentation, preliminary work is required for two reasons. First, it aims to test whether the connection and process between brainwave device and Cloud APIs can work fine. Second, it helps researchers identify the execution time required to process data and present data in visualization. Preliminary work involved with a pair of volunteers dancing, and most of dancing moves were salsa [22]. Each volunteer had attached the brainwave device. In another preliminary test, it was confirmed that the device did not affect the quality of data recorded in the brainwave device. Preliminary tests were conducted so that each API could process datasets and had their execution time recorded. Execution time on five occasions was taken to get an average execution time with their standard deviations. Results are based on the processing of collected 4,000 datasets described in Section 3 and 4A. Results are presented in Table 2.

Results in Table 2 show that all the average execution time is completed between 4.09 and 5.28 seconds, with standard deviations of between 0.04 and 0.06 seconds. The reason why some APIs take slightly longer time is that the time to record data from each region for the device and in data processing is dependent on the position of the brain segmentation.

Table 2: Average execution time for different Cloud APIs

Cloud APIs	Average execution time (sec)	Standard deviation (sec)
UpperFrontLobe	5.28	0.06
LowerFrontLobe	5.16	0.05
UpperParietalLobe	5.23	0.06
LowerParietalLobe	5.14	0.05
OccipitalLobe	4.86	0.05
LeftTemporalLobe	4.35	0.05
RightTemporalLobe	4.46	0.05
LeftCerebellum	4.23	0.04
RightCerebellum	4.31	0.05
UpperBrainStem	4.18	0.04
LowerBrainStem	4.09	0.04

Dancing is an activity that requires a lot of body movement and co-ordination. Thus, brain stem and cerebellum, the most relevant regions in the brain segmentation, are most likely to be filled in datasets and be completed the data processing and visualization the quickest. Results confirm this hypothesis in H1 since all data processing in the lower brain segments can be completed quicker than the upper brain segments. Whereas regions away from brain stem, are less likely to be filled with datasets [23]. Data processing is thus the mostly likely to be completed later than those in the lower brain segments, as evident in the results of Table 2. Low standard deviations suggest that collected datasets and data processing with read, process and visualize steps (described in Section 4A) are consistent with each other. Results confirm hypothesis one that there is a shorter execution time to process data in the lower brain of segments than the upper segments.

V. Cloud Segmentation – Actual Experiments and Brain Segmentation

This section describes the actual experiments and its results in execution time and visualization. Different tests were undertaken to ensure that Cloud APIs can produce results quickly, accurately and effectively.

A. Actual Experiments

As discussed in Section 2B, eight pairs of volunteers took part and their brain response waves were recorded and then processed by Cloud APIs. All of them had dancing experience, but stopped dancing for at least two years. The objective is to understand how they could recapture their skills, and the respective brain activities (reflected in segmentation).

Table 3: Average execution time for different Cloud APIs

Cloud APIs	Average execution time (sec)	Standard deviation (sec)
UpperFrontLobe	4.98	0.11
LowerFrontLobe	4.86	0.10
UpperParietalLobe	4.95	0.10
LowerParietalLobe	4.81	0.10
OccipitalLobe	4.64	0.10
LeftTemporalLobe	4.14	0.09
RightTemporalLobe	4.25	0.09
LeftCerebellum	4.01	0.08
RightCerebellum	4.07	0.08
UpperBrainStem	3.92	0.07
LowerBrainStem	3.85	0.07

Execution time on five occasions was taken to get an average execution time with their standard deviations. Results are presented in Table 3. Comparing to Table 2, results in Table 3 show that there is overall shorter average execution time. The most sensible explanation is that in a larger dancing group, many volunteers were very delighted, with very happy movement and shouting of joy all the times. As a result, it was quicker to fill the device with the required number of datasets from the lower sgments of their brains. This supports the hypothesis.

There is an average between 0.20 and 0.24 seconds quicker across all APIs. However, the standard deviations widen due to a higher number of volunteers involved, but the difference between 0.07 and 0.11 is an acceptable range. Average execution time in the last four APIs are between 0.22 and 0.24 seconds shorter than the counterparts in Table 2, which may mean that it is quicker to be filled with datasets and be ready for processing. On the other hand, average execution time in the first four APIs still takes longer time than the average of all APIs due to the distance and less relevance to dancing.

B. Brain segmentation

As discussed in Section 2, the objective is to study how volunteers respond when they reuse a skill, which they learned at least two years ago but did not practice before the start of the experiment. When all the datasets are processed, each API computes a numerical value corresponding to the intensity of each region in brain segmentation. Visualization is the end result of such representation. Figure 2 shows the diagram the collective result of brain activities while recapturing dancing skills. It shows different levels of brain activities in the frontal lobe, parietal lobe, occipital lobe (these three are grey matters, the last one is situated at the back), temporal lobe consisting of corpus callosum and hippocampus (inner brain, the later one controls emotion) and brain stem (middle brain).

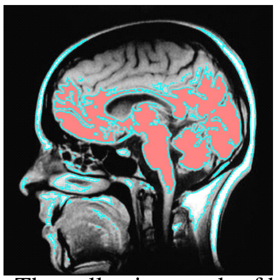

Figure 2: The collective result of brain activities while recapturing dancing skills

The result shows that brain activities in the lower frontal lobe, lower parietal lobe and occipital lobe are reacting actively. The entire brain stem and temporal lobe are responding very positively and the intensity level is at the highest. This may mean volunteers require a high level of balancing. When they dance, their movement is fast, and must keep themselves balanced with swift but steady movements.

The areas that represent the emotions are not so obvious but still can be seen with some activities. Experimental results also agree with existing theories [16-22].

C. Numerical values for the intensity level

This section presents numerical values corresponding to Figure 2, where Table 4 shows the numerical results of the volunteer's collective brain intensity. APIs with high numerical values mean that they have high brain activities during the experiments. Results in Table 4 support hypothesis because the lower segments of the brain have the higher numerical values than the upper segments of the brain.

- Occipital Lobe – The ability for vision is enhanced because eyes need to capture various dancing movements in a short period of time.
- LeftTemporalLobe – The ability for controlling all of behaviors, hearing, storing new memory and vision is improved and can react to fast changes in dancing.
- RightTemporalLobe – Same as LeftTemporalLobe except it has higher values. A likely reason is that dancing is considered as arts and the right side of the brain processes most of interpretations related to arts than the left side of the brain.
- LeftCerebellum – The ability to control balance and co-ordination is greatly enhanced due to fast and skilled movements required by dancing.
- RightCerebellum – Same as LeftCerebellum except it has a marginally higher value. A likely reason is that right side of the brain processes more interpretations than the left side.
- UpperBrainstem and LowerBrainstem – both have a numeric value equal to 1.000, the highest value recorded. This means that in dancing, human body reacts fully to control blood pressure, breathing, consciousness and heartbeat to ensure that dancers can be fully ready for dancing movements.

Table 4: Average execution time for different Cloud APIs

Cloud APIs	Average numerical value (out of 1)	Standard deviation
UpperFrontLobe	0.024	0.010
LowerFrontLobe	0.705	0.111
UpperParietalLobe	0.022	0.009
LowerParietalLobe	0.717	0.115
OccipitalLobe	0.991	0.009
LeftTemporalLobe	0.915	0.025
RightTemporalLobe	0.919	0.025
LeftCerebellum	0.986	0.008
RightCerebellum	0.990	0.015
UpperBrainStem	1.000	0.001
LowerBrainStem	1.000	0.001

VI. THE USER EVALUATION

This section describes two types of user evaluations. The first type involves with two groups of medical cohorts, who use this brain segmentation technology as part of Medical Cloud Computing Education (MCCE) to study the learning efficiency and satisfaction before and after three months of trial periods. The second type user evaluation is to use this technology to recapture the results in other dancing groups, and only researchers are involved in this aspect of user evaluation to justify the followings:

1. This technology can reproduce results that had been performed before.
2. This technology can simulate other scenarios based on the data collected in this case study.

The second objective, if it is confirmed the case, can offer more cost-saving because there is no need to perform more experiments to justify results. In other words, the first experiment should include and collect as many results as possible, so that the collected results can be used as good reference points before considering set up another research. This also saves time, resource and effort to reset up experiments.

User evaluation is an important step to ensure that all testing results are validated and the brain segmentation technology can fulfill the design and deployment requirements. Additionally, use revaluation can confirm that the use of Cloud Computing can improve the quality of education by offering ease-to-use interfaces and a facility for medical students to understand the complex concepts with ease. Hence, a three-month evaluation was undertaken to justify that the use of brain segmentation Cloud Computing technology can meet the goals and objectives of improving the quality of education and also match the design and deployment requirements.

A. Results of the two medical cohort group

There are two medical cohort groups with fifteen in each group. They were introduced the use of Cloud Computing for medical training, and surveys were taken before and after the adoption of MCCE. Each student has used MCCE for at least three months. The focus of the study was to identify the rate of learning satisfaction before and after the introduction of MCCE. Survey questions were taken and an average score for learning satisfaction was recorded for each student. All the records are undertaken with statistical analysis presented in Table 1. The variable "group1_without_Cloud" indicates learning satisfaction for cohort group one before using MCCE and the variable "group1_with_Cloud" is the variable after using MCCE. Similarly, the variables "group2_without_Cloud" and ""group2_without_Cloud" are the same terminology for cohort group two. Mean is the percentage for learning satisfaction before and after using MCCE. Standard deviations are the difference between the average of the lowest/highest values and the mean value. By referring to Table 5, there are 20% improvement in learning satisfaction by subtracting the difference between "group1_with_Cloud" and "group1_without_Cloud", and between "group2_with_Cloud" and "group2_without_Cloud". The results confirm that there is positive feedback from students taking this pilot study.

Table 5: Statistical analysis for two medical cohort groups before and after using MCCE

Variable	Obs	Mean	Std. Dev.	Min	Max
group1_without_Cloud	15	69.33333	3.9036	60	76
group1_with_Cloud	15	89.4	3.601587	80	95
Variable	Obs	Mean	Std. Dev.	Min	Max
group2_without_Cloud	15	70.06667	3.494213	65	76
group2_with_Cloud	15	90.13333	2.899918	85	95

B. *Results of the two medical cohort group*

Analysis of variance (ANOVA) provides statistical test of whether means of several groups are equal and can generalize t-test or F-test to two or more groups [10]. ANOVA can be used when these two cohorts have close means and each group has two sets of data. Table 6 shows the ANOVA analysis with F-test for cohort group one, where "grp1_with_Cloud" is the shorter version of "group1_with_Cloud". Cohort group one has F-value = 2.78 and Prob > F is 0.1148 (the smaller, the better). The R-squared value is 0.7875 (the higher, the better) and the root mean square error (MSE) is 2.74874 (the lower, the better). These key results confirm that the statistical analysis agrees that the use of MCCE help medical students in their motivation for learning.

Table 6: ANOVA analysis for cohort group 1

Number of obs = 15 R-squared = 0.7875
Root MSE = 2.74874 Adj R-squared = 0.5042

Source	Partial SS	df	MS	F	Prob > F
Model	168	8	21	2.78	0.1148
grp1_with_Cloud	168	8	21	2.78	0.1148
Residual	45.3333333	6	7.55555556		
Total	213.333333	14	15.2380952		

Table 7 shows the ANOVA analysis with F-test for cohort group two, where "grp2_Cloud" is the shorter version of "group2_with_Cloud". Cohort group two has F-value = 8.93 and Prob > F is 0.0078. The R-squared value is 0.9225 and the root MSE is 1.48605. These key results confirm that the statistical analysis agrees that the use of MCCE help medical students in their motivation for learning.

Table 7: ANOVA analysis for cohort group 2

Number of obs = 15 R-squared = 0.9225
Root MSE = 1.48605 Adj R-squared = 0.8191

Source	Partial SS	df	MS	F	Prob > F
Model	157.683333	8	19.7104167	8.93	0.0078
grp2_Cloud	157.683333	8	19.7104167	8.93	0.0078
Residual	13.25	6	2.20833333		
Total	170.933333	14	12.2095238		

Comparing with Table 6, results in Table 7 show that there is a greater consistency in the datasets for cohort group two. A likely reason is that cohort group two has a smaller difference between the minimum and maximum values in learning satisfaction, and more people in cohort group two have results closer to each other while rating their learning satisfaction before and after using MCCE.

VII. Scientific Evaluation

This section describes how the collected data and the technology can be used to reproduce results in a way similar to the ones undertaken in another experiment. This needs not setting up another experiment, provided with the following conditions met.

1. All volunteers stopped dancing for two years. After the first session of undertaking the experiment (described between Section 2 and 4), volunteers recalled their dancing activities they learned in the past. A break of one hour was introduced, before heading to the next session. During the break, videos of other professional dancing movements were shown to them, in order to help them recall their memories and skills involved with dancing. Volunteers also rehearsed their moves, and had the opportunity to dance with their partners during the break.
2. Perform the second session of the same experiment described between Section 2 and 4. This means that the same group of volunteers was able to recall their memory and dance (given in a short time, such as 2 hours dancing and 1 hour of break time in between).
3. Although more time could be given, an objective is to test how humans can recall their lost skills or forgotten memory given with a short time was given. A reason of doing that is often in the work environments, training was provided, but many employers expect the employees to perform to their set targets given in a short period of time, such as medical training.

A. *The core area of the brain segmentation – how the brain responds while recapturing a lost skill*

Figure 3 shows how the human brain responds for recapturing a lost skill, dancing. Volunteers took very positive actions for their learning. This group of volunteers was extremely keen to rehearse the skills they learned, and was actively engaged in dancing. The experimental session was full of fun and enjoyment to explain why such hyper-activities were observed. Although hippocampus controls human emotions, the entire section is in full pink color. The dancing moves made volunteers very anticipated with a high level of emotions. As a result, all parts of the brain have hyper activities as indicated in the simulations. Figure 3 also shows that the volunteers have such high emotions that the entire brain is almost working at its own peak. In this case study, results confirm that positive learning can enlighten our learning capacities. If learners are involved in movement and are motivated and positive in the process of learning, there is a strong possibility to have improved learning outcomes. Other experiments and case studies will be conducted to consolidate this hypothesis.

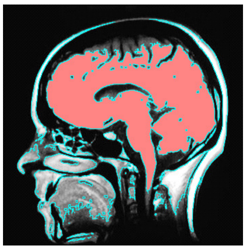

Figure 3: The core area of the brain segmentation (learning a new skill, eg dancing, for positive volunteers)

B. Numerical values for the intensity level

Similar to Section 5C, this section aims to demonstrate the numerical value in each brain segment collected and interpreted by the eleven APIs during the scientific evaluations undertaken by other scientists. All the background information is the same as described in Section 5. The results are presented in Table 8 and likely reasons are explained.

Table 8: Average execution time for different Cloud APIs

Cloud APIs	Average numerical value (out of 1)	Standard deviation
UpperFrontLobe	0.415	0.085
LowerFrontLobe	0.901	0.103
UpperParietalLobe	0.632	0.098
LowerParietalLobe	0.913	0.112
OccipitalLobe	0.997	0.003
LeftTemporalLobe	1.000	0.002
RightTemporalLobe	1.000	0.002
LeftCerebellum	1.000	0.001
RightCerebellum	1.000	0.001
UpperBrainStem	1.000	0.001
LowerBrainStem	1.000	0.001

Results show that the last six APIs have the numerical value as 1.000. This means that all six brain segments receive the maximum level of electrical signals during the dancing activities. It means all the participants' heartbeat, blood pressure, emotion, balancing and vision were at the peak during their dancing session. On the other hand, the first five APIs do not receive the numerical value as 1.000, since their corresponding brain segments are focused more on behaviors, intelligence, memory, language, sensation and vision. However, the first five APIs have much higher numerical values comparing to results in Table 4. The "OccipitalLobe" API is in particularly close to 1.000, since volunteers need to accelerate their visioning abilities in their fast-paced dancing movements.

C. Other areas of the brain segmentation – work in progress

There are other work-in-progress that the use of simulations helps to identify any new projects on offer and also allows scientists to think more in-depth about what our bioinformatics services should provide. Figure 4 shows the outer area of the brain segmentation, which are closely related to brain analysis. First, the outer area forms a protective layer to prevent the human brain from damage as a result of accidents. Second, the outer area can be helpful to calculate the ratio of the size between the brain and the outer layer. This is helpful to some surgeons in terms of counting the number of tumors started or close to the outer region, particularly areas near the spinal cord and pituitary gland, which may cause permanent damage and death. However, how these tumors develop is still not entirely known, and it is easier to find out from the outer layer rather than within the brain.

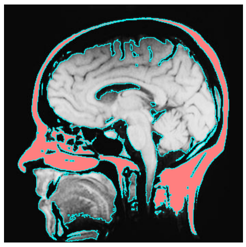

Figure 4: The outer area of the brain segmentation

D. Summary of scientific evaluation

Given with the results presented in the previous two sub-sections, all volunteers were able to recall their lost skill. The collected datasets and results presented in Figure 3 in particular, confirm that their brain activities were at the fullest extent of usage. This means that in a short period of time, if humans can be pushed to the limits (but must be done appropriately, and not in harsh conditions), it is possible that memory can be retrieved and the entire brain also becomes active to help perform the given tasks. Results presented in Table 7 confirm that volunteers had their heartbeat, blood pressure, emotion, balancing and vision at the peak during their dancing session. Their behaviors, intelligence, memory, language, sensation and vision are higher than results in Table 4. While recapturing their skills, brain segments on the memory (frontal lobe and temporal lobe) have higher level of activities on the volunteers. The collected datasets can be reused many times to reproduce the same or similar results. This also confirms that the introduced Cloud Computing segmentation technology can provide added values in producing simulation results and save long-term costs.

VIII. DISCUSSIONS: BENEFITS OF USING CLOUD COMPUTING

This section describes the benefits of using Cloud Computing for scientific research. Topics of discussions include reproducibility and reusability of results; cost-savings; benefits to education and future research questions.

A. Reproducibility and reusability

Reproducibility is an important aspect in Science that similar results should be reproducible while following steps and recommendations from the previous experiment [24]. Experiments involved with physical and biological science have this characteristic in common to ensure results are reproducible when working in the same scientific conditions. Apart from reproducibility, reusability is important. Since large-scale experiments can take a lot of funding and time for planning and execution, it is desirable that part of, or the entire set up or results of any scientific work can be reused.

Cloud computing for brain segmentation technology can meet reproducibility and reusability described as follows. First, results of experiments in Section 4 fully agree with the theories. Brain segments that are closely related to movement, co-ordination, behaviors, memory, hearing, vision, breathing, heartbeat, blood pressure and consciousness have hyper activities. Second, each experiment was conducted five times to get the average result. Each time results for each of ten brain segments have similar outcomes with a small standard deviation ranging from 0.001 and 0.111. In the case of reusability, the most expensive part was the technical set up of the experiments. Once the set up and experiments were completed, results were recorded in the Cloud Computing brain segmentation technology service. Data can be used to represent the collective results of the investigation without purchasing or renting the equipment to set up. This can save several thousand pounds for set up fee each time. Results can be computed in the form of numerical values or 3D simulations showing the activities of each brain segment in regard to dancing. Cloud computing simulation can be reused at any time without the set up and results of the collective effort can be used to analyze the impact between learning and brain activities [13].

B. Cost-savings

Similar research can take years to get comparable results and they may cost millions of British pounds. Often the organizations that receive funding are Cancer Research UK or Neurophysiology. At the NHS, the emphasis is on medicine as they offer NHS Practitioner Training Program. The exact expenditure is not enclosed to the public. However, the estimated cost can be analyzed briefly as follows. The project can cost multiple millions to offer training, and other multiple millions to provide facilities and another few years of training and millions of investment are required in order to produce similar results as this research paper demonstrates. In contrast, the facility for this research cost, £81,000 set up, and another £2,000 for the loan of equipment. The volunteers and collaboration with University of London Computing Center (ULCC) and KCL are free of charge.

According to NHS statement, the NHS will spend £110 billion in 2015/2016 year, a 0.1% increase of current spending [25]. While searching for various references and public reports, NHS does not give an exact figure on IT spending. Based on the author's previous experience working with the NHS, 1% of the budget spending on its national IT application and infrastructure (such as Electronic Patients' Records) is perhaps a good estimate. Assuming 1% of £110 billions is spent in the NHS, an estimated 1.1 billion pounds of IT spending is used annually. However, the NHS efficiency, including IT services are criticized by the public [26]. In some cases, millions of pounds are spent without delivering services. Or three times more than the original budget is required to deliver. Some IT projects above £1 million do not support reproducibility and repeatability in contrast to this project. Altogether the cost of this project is only £83,000 excluding the extra time and effort, which fully meets the tight budget. This amount of spending between 2009 and 2011 is only 0.754% of the estimated spending by the NHS UK in a year. This project can demonstrate a high extent of cost-saving if the right level of skills and competency are implemented for the healthcare informatics, without the need to apply for extra funding and extended delivery deadline.

C. The benefits to education

Chang [13] presents an evaluation and statistical analysis of two medical cohort groups based on the implementation of this brain segmentation technology. The results confirm that Medical Cloud Computing Education" (MCCE) can improve 20% of learning satisfaction. Two medical cohorts show more interests and acknowledgment in the use of Cloud Computing blending with medical education. Statistical results confirm a good extent of accuracy in analysis by having high R-squared values; low root mean square values and high F-test values. The variations in p-value have been explained by the variations before and after using Cloud Computing for education. Based on direct feedback from some participants, MCCE can enhance learning and understanding of complex science such as brain segmentation.

Similarly, Cloud Computing can be used for education to produce similar outcomes. There are case studies described as follows. First, the University of Southampton adopted Cloud Computing. It was reported to offer added values for two departments, Electronics and Computer Science (ECS) and the iSolutions Group, where cost-saving exceeded 20% for ECS and service improvement had around 4 to 8% compared to the previous years [6, 15]. Second, the University of Greenwich used Cloud Computing to deliver supply chain courses. It was reported to have 15% improvement in learning satisfaction and students could achieve higher academic performance of up to 15% while using Cloud Computing for education. Lecturers could save efforts to repeat same lectures over the period of time due to the use of simulations to simplify explanations of complex supply chain concepts [10]. Third, it was reported that King's College London, NHS and University of Oxford adopted Cloud Computing and could offer better quality of teaching and IT services for stakeholders, scientists and students [4, 9, 11-13]. The use of Cloud Computing is crucial in the curriculum development and IT services at these universities based in the UK.

D. Achieving the overall success

As explained in the introduction, an objective is to achieve an overall success of the project delivery to meet stakeholders' requirements. The criteria are based on technical implementations, user evaluation and fund management. This paper demonstrates that the use of the wireless, Cloud computing and brain segmentation technologies can jointly deliver technical design and implementation. Two aspects of user evaluations have been presented. The first type involved the two medical cohorts who could evaluate the added values before and after using the MCCE, an adapted service of brain segmentation technologies. The second type involved with the scientific evaluations to investigate how human response while recapturing a skill and their respective numerical values recorded. The entire project can be managed within £83,000 to deliver a proof-of-concept and valuable service for medicine.

This has better fund management than multi-million projects that keep the costs down and ensure delivery on time.

E. Future research questions to investigate the relationship between brain segment and learning

The relationship between how brain activities respond and learning can be aided by brain segmentation technology. This should include investigations to understand how people learn. Research questions include the following: "When each volunteer learn a new theory, how their brains react and which segments are the most active?"; "Does each person vary different in different parts of the brain segments while learning the same thing?"; "Do people from different ethic background react differently in their brain segments while learning the same thing?"; "Are there any ways to stimulate learning process and produce better learning efficiency?". With the understanding with brain segmentation, it can help more people understand between learning and brain activities. These include how to improve our learning outcome when we can learn new skill, and also when we recapture a skill that was not practice for some time. The use of Cloud Computing helps us produce simulations to understand the process of learning.

IX. CONCLUSION AND FUTURE WORK

This paper introduces the brain segmentation technology offered by Cloud Computing. It first explained the APIs associated with each brain segment, as well as the process of capturing data in regard to each segment. The background information on micro sensors and the infrastructure, and their relations to Cloud APIs were explained. Dancing was chosen because data related to fast and skilled movements could be captured more easily. The results captured for each brain segment were discussed, and agreed with the theories that some segments are more active in dancing. The average execution time for each API was presented and all analysis could be completed in seconds. Furthermore, two evaluations were presented. The first evaluation was based on brain segmentation used by Medical Cloud Computing Education (MCCE). Results of analysis confirm that Cloud Computing can offer 20% improvement in learning satisfaction for two cohort groups. Outputs of ANOVA analysis were presented to confirm that the benefits of using MCCE to improve the quality of education. The second evaluation was based on recapturing a lost skill undertaken by scientists. Eleven Cloud APIs were used to collect data from volunteers. Results show that volunteers had higher level of brain activities across all brain segments, particularly the ones in control of blood pressure, heartbeat, vision, co-ordination and physical behavior. Results also support the use of brain segmentation technology in unlocking the links between the memory and a lost skill (dancing).

Benefits of using Cloud Computing with brain segmentation technology were presented. Reproducibility and reusability were supported. Cost-savings were achieved, as the expenditure in 3 years was only 0.754% of the estimated spending by the NHS UK each year. Benefits to education were illustrated by this case study, and with successful deliveries at the Universities of Southampton, Greenwich and Oxford and also KCL and NHS. Plan for the future work is as follows. More studies involved with body movements such as dancing will be investigated and more sample sizes will be included. Future collaboration with more research institutes will be strengthened to jointly deliver more funding and publication. The use of Cloud Computing can make positive impacts to healthcare informatics and education by demonstrating overall success in technical implementation, satisfactory user evaluations and good management of cost-savings.

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