Jurnal Ilmiah PPI-UKM
Scientific Journal of PPI-UKM
Persatuan Pelajar Indonesia
Universiti Kebangsaan Malaysia
Selangor, Malaysia

Scientific Journal of PPI-UKM

Sciences and Engineering

ISSN No. 2356 - 2536

The Scoring Quality of Astronauts' Sleeps Using Fuzzy C-Means (FCM) During Microgravity Effect in The International Space Station (ISS)

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Abstract

For successful health programme of Japanese astronauts during space activity in the International Space Station (ISS), we looked into the sleep quality of astronauts by using Fuzzy C-Means (FCM). At the first step, we collected observation data by following sleep schedule of astronaut Noguchi for fifteen days (26 July 2005 to 9 August 2005) during STS-114 spaceflight. The Fuzzy C-Mean (FCM) was used to design the score quality of astronauts' sleeps. We defined three condition of sleep quality (e.g. sleepy, sleep, deep sleep) with the minimum score (zero) and maximum score (nine). Based on the preliminary result, we found that the minimum sleep score of astronaut Noguchi was from 7 to 9 August 2005 which was due to landing process and the maximum sleep score we found was later than 27 July 2005 during docking on ISS.

Keywords: International Space Station (ISS), Fuzzy C-Means (FCM), Scoring, and Sleep quality

1. Introduction

The microgravity effect is a synonym of weightless effect [1]. It means that we can move the heavy object only using fingers due to the very small gravity on low earth orbit area (http://www.nasa.gov/audience/forstudents/k-4/stories/what-is-microgravity-k4.html#.VMr4l9KsVA1).
In fact, microgravity is very harmful for astronauts during docking on International Space Station (ISS) and has effects on their sleep quality. Many astronauts experience health problem such as insomnia once they return to Earth. In current research on microgravity effect studied by Ann. R. Elliott et al., microgravity effect can reduce human sleep [2] time during space activity. The authors found that the reduced sleeping time achieved 16.5+3.0% of total sleep time pre-flight as compared to 0.7+0.5% in-flight. Also, Ying Ho et al who studied scoring method using Evolutionary fuzzy classifier for tumour prediction [3] predicted tumour evolution. They found the minimum score of tumour prediction to be zero and maximum score was 100.

In this study, we used fifteen days (26 July 2005 to 9 August 2005) period during STS-114 spaceflight by looking into the sleep schedule of astronaut Noguchi. This work aimed to assist in finding score (value) of the astronauts' sleep quality using Fuzzy C-Means (FCM) during microgravity effect in International Space Station (ISS) and to propose astronauts' sleep schedule during space activity.

2. Materials and methods

The main goal in this study was to use data observation from sleep schedule of astronaut Noguchi during STS-114 spaceflight. In this work we selected sleep time (St) and days (d) with interval 24 hr (daily basis).

2.1. Methodology

This work contained three steps. The first step was data collection with two variables. Then, we used MATLAB software for data processing in the second step. Finally, the third step was using Fuzzy C-Means (FCM) to create cluster with number of scoring quality for the astronaut's sleeps.

2.2. Data Processing

After data was collected from http://iss.jaxa.jp/med over fifteen days (26 July 2005 to 9 August 2005) observation, the data was sorted and cleaned using MATLAB program.

2.3. The Microgravity effect

Microgravity is gravity phenomena with low value that generally occurs in low earth orbit (see table 1).

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Table 1
Gravity due to Earth and Sun [4]

Location	Gravity due to Earth	Gravity due to Sun	Total
Earth's surface	9.81 m/s^2	6 mm/s^2	9.81 m/s^2
Low Earth orbit	9 m/s^2	6 mm/s^2	9 m/s^2
200.000 km from Earth	10 mm/s^2	6 mm/s^2	12 mm/s^2

2.4. The position of astronaut's sleep

During space activity in low orbit, astronauts had bad quality sleeps. This sleep position is not healthy due to microgravity effect in this area (9 m/s2). The astronaut's arms would go up and forward and at the same time, losing strength as shown in Fig. 1.

Fig. 1. The position of a sleeping astronaut in low orbit [http://iss.jaxa.jp/med/healthy_sleep_en.pdf]

2.5. Fuzzy C-Means (FCM)

The scoring design of astronaut's sleep quality using Fuzzy C-Means (FCM) in this study consisted of three conditions which were sleepy, sleep and deep sleep. The strongest FCM method was introduced by Bezdek et al with the equation given as [5]:

$$J = \sum_{k=1}^{n} \sum_{i=1}^{c} \mu_{ik}^{m} \left\| X_k - V_i \right\|^2, \qquad 1 \le m \le \infty$$

Where:

n = number of point data
c = number of cluster
X_k = kth data point
V_i = ith cluster center
i_k = degree of membership of the kth data in the ith cluster
m = constant greater than 1 (typically, m =2)
J = predict value
k = constant data
μ = rule input

3. Result and Discussion

Table 2 showed the sleep schedule of Astronaut Noguchi during STS-114 over fifteen days (26 July 2005 to 9 August 2005). As can be seen in the table, space activity processes such as launching, docking, and undocking and landing have different duration of sleep. During launching to docking process, sleep quality of the astronaut increased. However, the undocking and landing process decreased the astronaut's sleep quality due to activity of returning to Earth. Once back on Earth, they faced health problems like insomnia. Current study after mission in space revealed that 20% of the astronauts took hypnotic drugs during spaceflight (http://iss.jaxa.jp/med) due to difficulties in walking and falling sleep.

Table 2
Sleep schedule during STS-114 (Spaceflight of Astronaut Noguchi) [http://iss.jaxa.jp/med]

Date	Duration of Sleep (Average)	Activity
July 26, 2005	NaN	Launching
July 27, 2005	4 Hr	-
July 28, 2005	2.89 Hr	Docking
July 29, 2005	2.89 Hr	-
July 30, 2005	2.89 Hr	-
July 31, 2005	2.89 Hr	-
August 01, 2005	2.21 Hr	-
August 02, 2005	2.21 Hr	-
August 03, 2005	2.21 Hr	-
August 04, 2005	2.21 Hr	-
August 05, 2005	1.66 Hr	-
August 06, 2005	1.66 Hr	Undocking
August 07, 2005	0 Hr	-
August 08, 2005	0 Hr	-
August 09, 2005	0 Hr	Landing

The NaN data on July 26, 2005 indicated no data, meaning that the astronaut had trouble sleeping. Table 3 showed the sleep condition scores of sleep defined in three clusters. The maximum scoring value (7 to 9) was given to deep sleep condition while minimum value (0 to 2) was given to sleepy condition (see table 3).

Table 3
The scoring of astronaut's sleep condition

No.	Scoring Value	Sleep Condition
1.	0 – 2	Sleepy
2.	3 – 6	Sleep
3.	7 – 9	Deep sleep

Fig. 2 showed the duration of sleep of Astronaut Noguchi during STS-114 over fifteen days (26 July 2005 to 9 August 2005) where data of duration sleep has been normalized. Based on the Fig., green symbol (*) is a correlation index one due to “Sleep” status, red symbol (*) is a correlation index two due to “Sleepy” status and blue symbol “O” is a data index for sleep duration.

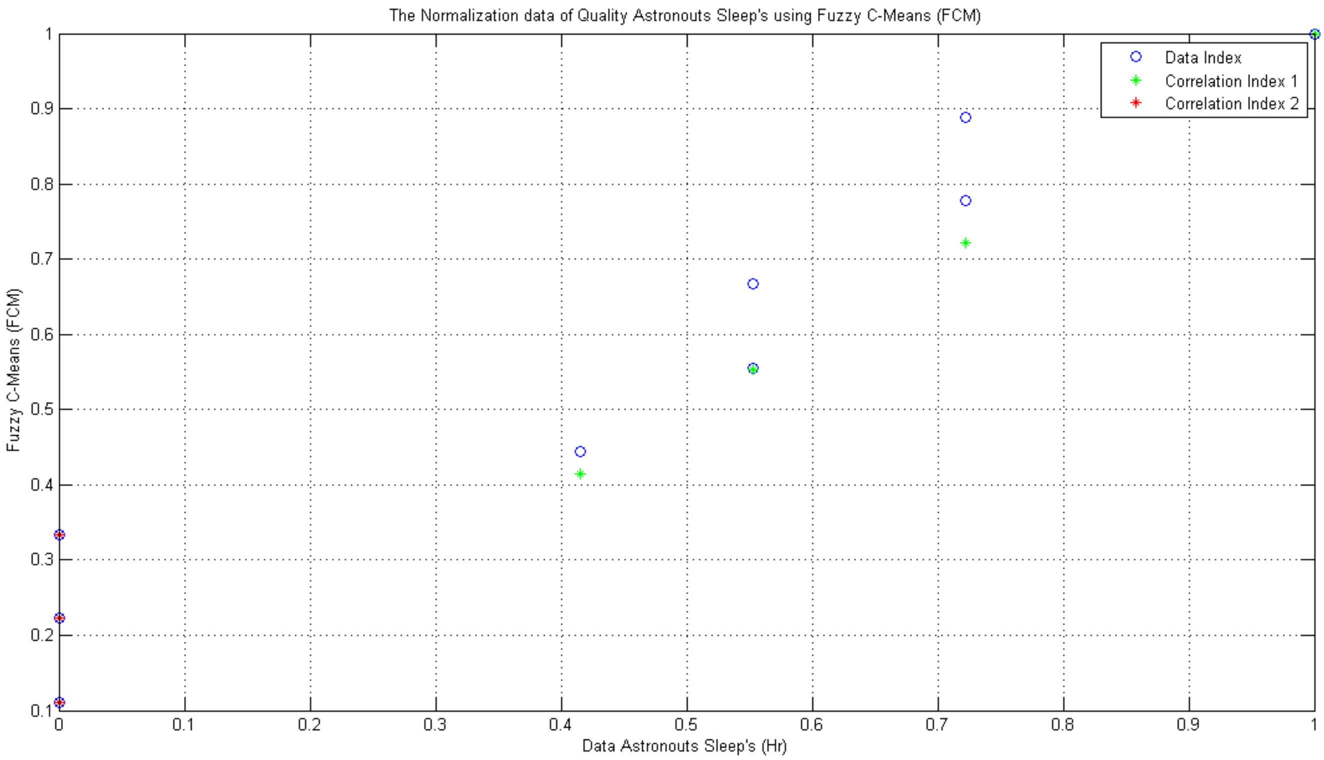

Fig. 2. The Normalization data of Quality Sleep's using Fuzzy C-Means (FCM)

The Fuzzy C-Means (FCM) revealed that sleepy condition has the strongest correlation (red symbol) with index as compared to sleep condition (green symbol). Moreover, sleep and deep sleep conditions have good correlation as indicated by the green symbol.

The microgravity effect worked from 28 July until 6 August 2005 during docking and undocking spacecraft. Therefore, astronauts would experience sleep problem especially with arm position that go up and forward, causing lost of strength, hence, such sleeping position is not comfortable for astronauts.

4. Conclusion

Preliminary study on scoring of astronaut's sleep quality was successfully performed using Fuzzy C-Means (FCM) during STS-114 spaceflight. Minimum score (zero) and maximum score (nine) were applied to define sleep condition. It is found that minimum sleep score of Astronaut Noguchi was from 7 to 9 August 2005 during landing process while maximum sleep score was after 27 July 2005 during docking on ISS. We also discovered that sleepy status has the strongest correlation index as compared to sleep and deep sleep status. The microgravity effect has worked from 28 July until 6 August 2005 during space activity and many astronauts have sleep problem due to their arm position that went up and forward, causing loss of strength. In near future, we will estimate sleep quality using Artificial Neural Network (ANN) to evaluate health condition of astronauts during space activity.

Acknowledgment

We would like to thank the Japan Aerospace Exploration Agency (JAXA) for providing the data and Ms. Siti Katrina Zulkeple for her contribution in this paper.

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