45th Annual ATCA Conference, Oct. 22-26, 2000
Taj Mahal Casino Resort Hotel, Atlantic City, New Jersey, U.S.A.

Fatigue and Drowsiness Predictor for Pilots and Air Traffic Controllers

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1. Introduction

Flight safety is heavily reliant on the performance of all those participating in aviation, and supporting the human element is a key to further enhancing aviation safety. Aircraft manufacturers continue to improve the design of their aircraft cockpits according to the results of studies and experiments on human factors; airlines conduct Cockpit Resource Management (CRM) and Line Operation Flight Training (LOFT) programs to enhance the performance of flight crews. However, nobody can believe that incidents and accidents will be totally eliminated, though airmen make every effort.

Some helicopters incorporate a Health and Usage Monitoring System, which constantly monitors the condition of various vital components in order to measure fatigue, to predict failures, and to improve maintainability. If it were possible to monitor the condition of the flight crew in real-time, this would enable flight deck human factors to be managed to some extent. Crew fatigue is a very real problem, especially on long-haul flights crossing many time zones. If an increase in the probability of crew micro-sleep and/or human error could be detected, it might be possible to warn the pilot so that he or she may be relieved by other on-board crew members. Such a monitoring system could be installed as airborne equipment if it were made sufficiently compact.

ENRI and OGIS-RI have been studying ways of measuring human performance since 1998. As part of these studies, a prototype system was constructed in 1999 to measure the fatigue and the probability of occurrence of drowse of a human subject in real-time by analyzing his or her voice.

2. Strange Attractor of the Human Voice

Historically, many methods have been proposed for measuring human performance characteristics, but these require that subjects perform certain tasks specifically for the purposes of the measurement. These methods therefore cannot measure the performance of a subject doing a task in real-time without imposing some sort of interference. However, for flight safety monitoring, a way of measuring crew performance in real-time is required that does not interfere with normal activities.

According to Chaos Theory, it is possible to measure various human characteristics by examining the strange attractors derived from sampled data of certain signals. If it were possible to derive the strange attractor of human vocal signals and to calculate its Liapunov exponents in real-time, this would enable human performance characteristics to be measured in real-time non-intrusively.

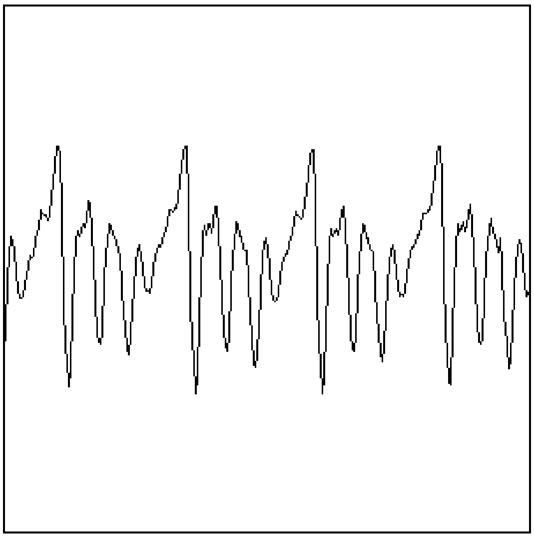

Fig. 1: Signal of voiced "a" sound: normal

Figure 1 shows an amplitude versus time trace of a human voice. Experiments have determined that the fractal dimension of the human voice is about 5~6. The strange attractor of the voice signal can be derived from sampled data, and an example is shown in Fig. 2.

In our prototype system, vocal signals are sampled at a rate of 11,025Hz (8 bits/sample), and about one second of sampled data is necessary to calculate Liapunov exponents when the strange attractor is formed in four-dimensional Takens space. The time to calculate the Liapunov exponents in this four-dimensional space can be reduced to less than ten seconds on a personal computer equipped with a 500MHz Intel Pentium III processor by using Sano and Sawada s algorithm.

Using this prototype, the performance of a speaker can be measured approximately every ten seconds. A Fatigue and Drowsiness Predictor could be realized as highly portable or even wearable equipment.

If it is necessary to calculate the Liapunov exponents in five-dimensional space, more than ten times the amount of data is required than for the 4-D calculation, and it is impossible to calculate the exponents in less than several minutes on a normal personal computer.

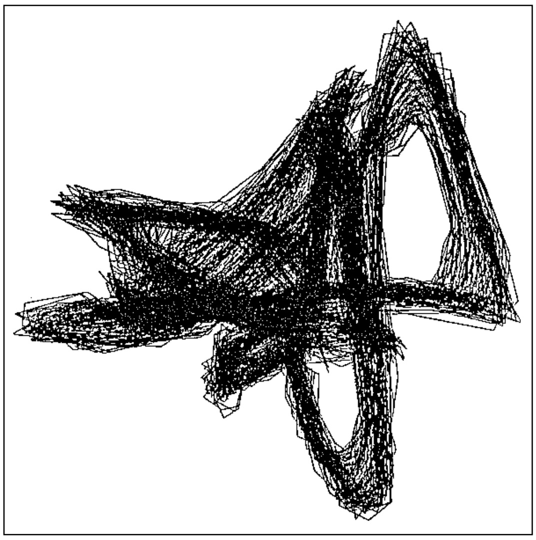

Fig. 2: Strange attractor of voiced "a" sound: normal

3. Fatigue and Drowsiness Predictor

The strange attractor of the human voice changes over time. It has been observed in experiments that the first Liapunov exponent calculated from the human voice s strange attractor increase before subjects start to feel fatigued or sleepy. At the start of an experiment, the first Liapunov exponent calculated from the strange attractor of a normally alert subject s voiced a sound was about 145 (Fig. 2). This increased to 367 after about thirty minutes of speaking. The change in the strange attractor can be seen in Fig. 3. Fig. 4 shows how the first Liapunov exponent of the voice strange

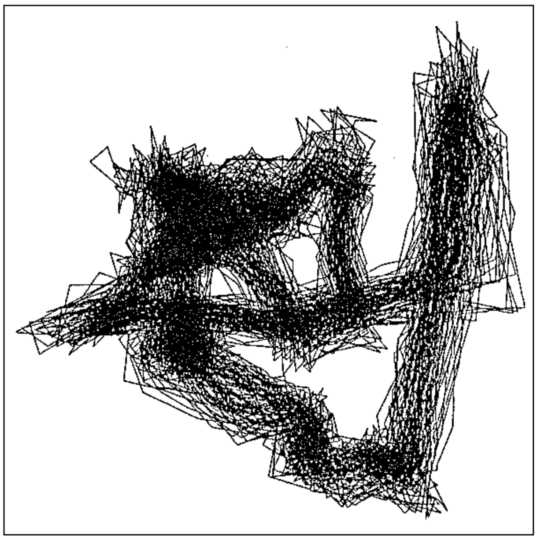

Fig. 3: Strange attractor of voiced "a" sound: fatigued

attractor changed during the course of the experiment.
From this experiment, it is thought that the human voice strange attractor s Liapunov exponents indicate the mental and physical condition of a subject.

4. Conclusion

Research and development of a Fatigue and Drowsiness Predictor has been carried out. This predictor can estimate fatigue and probability of occurrence of drowse from a subject s voice. The predictor has been developed on a personal computer as an application of digital signal processing based on the theory of Chaos, and is designed to work in real-time. The Fatigue and Drowsiness Predictor should be able to predict micro-sleep and drowse of pilots and air traffic controllers from their verbal communications. We believe that this will establish a new way of improving flight safety.

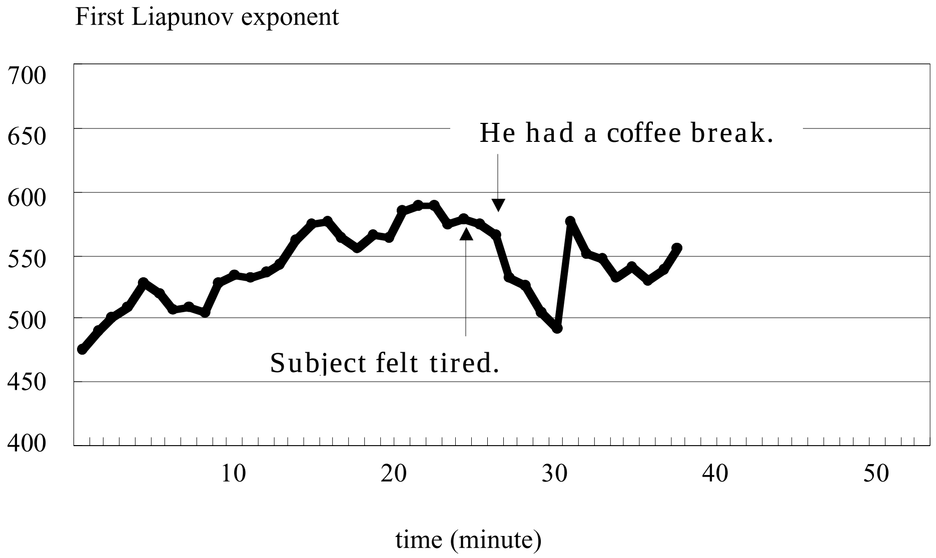

Fig. 4: Variation of human voice first Liapunov exponent