An Evaluation System of Mental WorkloadBased on the QN-MHP under Multi-taskCondition

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***Abstract*—In the traditional cockpit display-control system, pilots have to face more and more instruments and response to the complex information simultaneously. In order to study the change characteristics of the mental workload under such multi-task condition, take the virtual instruments for design objects to set up a series of tasks. With the increase of information quantity and frequency of m instruments, the task becomes more difficult. Then the QN-MHP is established to evaluate mental workload according to the information characteristic of above tasks and information processing manner of human. At the same time, carry out the corresponding EEG verification experiments with Neuro scan SCAN-40 equipment, and uses EEG energy ratio as validation standard. The EEG experiment result verifies that this model is feasible and efficient. This method can't only avoid experimental dependence of traditional subjective and objective tests, or the instability of the mental workload process, but also refrain the subjective error in the NASA-TXL test, so that the evaluation results get more accurate.**

Keywords—Queuing; Network-Model; Human; Processor (QN-MHP); Mental; Workload; EEG; Virtual Instrument; Evaluation

I. INTRODUCTION

QN-MHP has a unique advantage in the analysis of the complex structure system under the parallel task or multiple tasks, and symbolic modeling can effectively describe the specific human behavior under different task. Robert Feyen [1] proposed QN-MHP model which reflects human cognitive

processes and combines the symbolic modeling and Queuing Network; Feyen, Liu, and Omer Tsimhonietc has studied human cognitive characteristics such as driving[2,3],target tracking[4],and auditory counting based QN-MHP model, and then put forward two sets of assessment index of mental workload: one use workload-P300 in Event-Related Potential (ERP) to reflect the degree of mental workload under tracking and auditory probe counting tasks [5]; the other use six parameters of the NASA-TLX scale to assessment the degree of mental workload under highway driving and adjust the information feedback frequency [6].

Actually QN-MHP model plays an important role in studying the mental workload degree of multi-tasks based on the human cognitive processes, but existing researches just focus on qualitative difficulty levels, and verify the results generally by the NASA-TLX Scale, which involves large subjective factors. Therefore, we take the virtual meters for example, quantitatively increase the difficulty gradients of tasks according to the information parameters of meters, and establish the mental workload evaluation model based on the QN-MHP. Verified and revised by EEG experiments, we see that the QN-MHP assessment of mental workload is simple and effective.

II. MULTI-TASK INSTRUMENT DISPLAY SYSTEM

In order to build a real environment, a multi-task driving testable is established. As the main part of the device, the instrument display system is based on GL-Studio [7] and VC++,as shown in Fig. 1. The system can be controlled directly by joystick based on low layer driver of it.

The multi-task interface is composed of three screens [8]. Pointer meters vary in quantity and speed according to different requirement. When it starts, each pointer rotates under the same speed at diffident original position. Once trigged, the pointer bounces back to the safety zone and rotates to the danger zone for the next time. The experiment process is divided into 9 tasks and each task lasts for 3 minutes, as shown in Fig.2. From task2 to task9, the subjects should manipulate the joystick to control the meters. During the two tasks' break at intervals, subjects should keep their eyes closed to have a rest. The whole process is automatically controlled by the program [9].

Fig. 1. Multi-task Instrument Display System

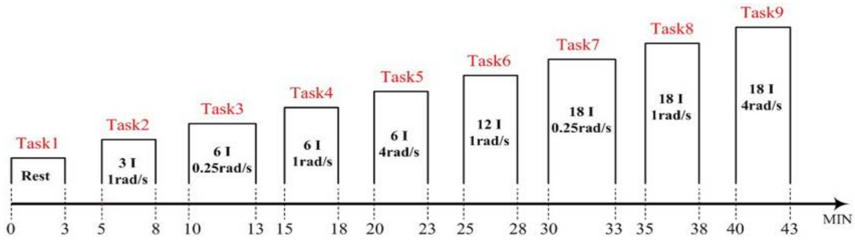


Fig. 2. Experiment Process

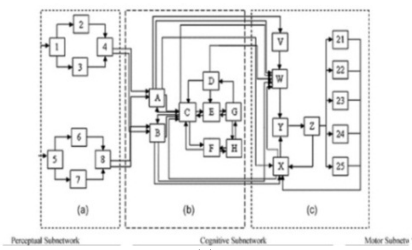
TABLE I. INFORMATION CHARACTERISTICS OF METERS

Entity \Tasks	Task1	Task2	Task3	Task4	Task5	Task6	Task7	Task8	Task9
Quantity each	0	3	6	6	6	12	18	18	18
Occurrence	0	28	7	28	112	28	7	28	112
Frequency	0	6.43	25.71	6.43	1.61	6.43	25.71	6.43	1.61

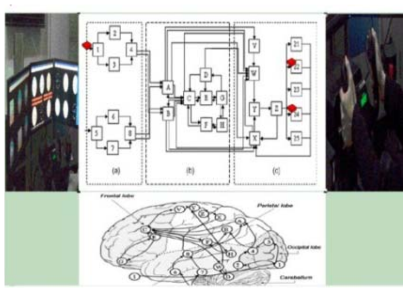
III. MENTAL WORKLOAD EVALUATION BASED ON QN-MHP

In QN-MHP,26 servers represent the different functional locations of the human perceptual, cognitive and motor system (Fig.3a). The information is firstly perceived by receptors, and then sent to the perceptual sub-network (1~ 4 location). After that, the information is sent to the cognitive sub-network (A ~H location) where analysis and processing occurs. Finally, the information arrives into the motor sub-network (V~Z, 21~25 location), and the locomotive organs begin to do movement correspondingly. The model is implemented in ProModel [10]. According to the information characteristics of meters, set the entity numbers and arrival rules in each task, as shown in Table 1.

Meter numbers and the speed ω are shown in Fig. 2, and each task stage is set to be 3 min. According to the cognitive research in neuroscience, we set the parameters of information processing for each location in the model. Among them, the average processing time of the perceptive, cognitive and motor sub-networks are respectively 42ms, 18ms and 24ms,while the minimum processing time is respectively 25ms,6ms,and 18ms,and all of them satisfy the exponential discrete distribution. After graphical construction and parametric setting, we run the QN-MHP model in ProModel, and the simulation interface is shown in Fig.3b



(a)



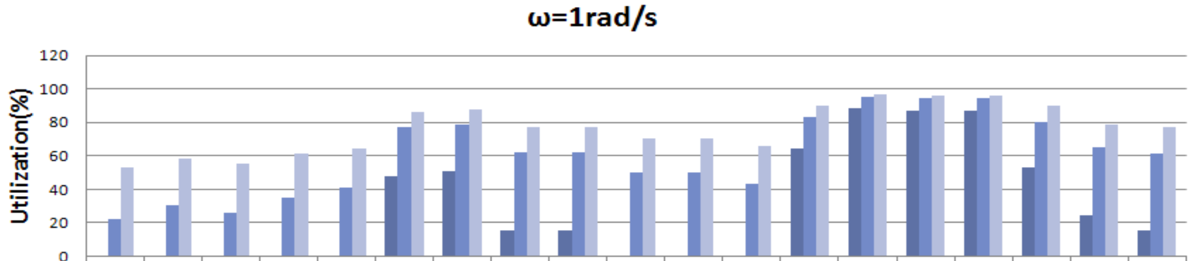
(b)

Fig. 3. Cognitive Model of QN-MHP (b) Simulation Interface of QN-MHP

According to the statistic results after simulation, we divide the utilizations of servers into two groups to get the change roles of mental workload under different tasks.

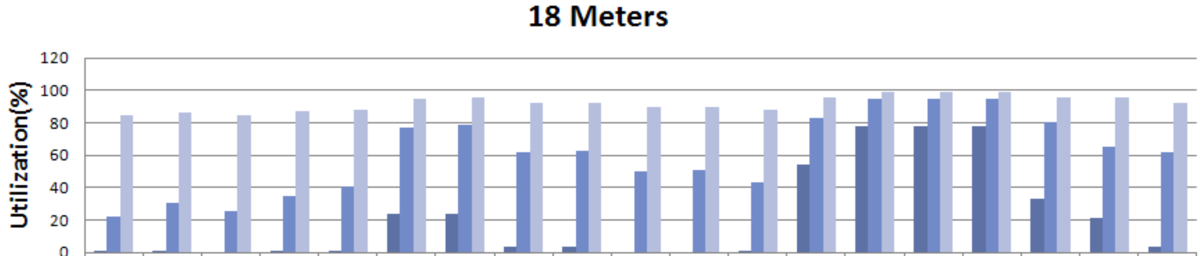
At a constant information frequency, from Task4, Task6 to Task8, server utilizations increase gradually along with the information amount of meters (Fig.4). On the other hand, when the information quantity of meters keeps constant, server utilizations are showed in Fig.5.

Taking the average utilization of all the location as the value of general QN - MHP mental workload, the results are shown in Fig.6. From Task4, Task6 to Task8,at a certain frequency of information, the mental workload gradually increase along with the quantity of information; from Task7,Task8 to Task9,at a certain quantity of information, as the frequency of information increases, the mental workload also increases gradually.



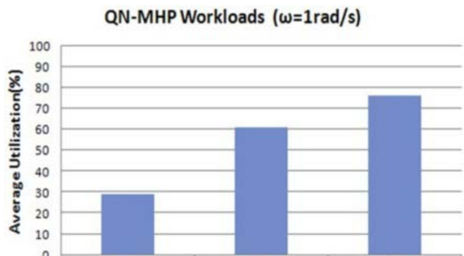
	Loc1	Loc2	Loc3	Loc4	LocA	LocB	LocC	LocE	LocG	LocF	LocH	LocV	LocW	LocX	LocY	LocZ	Loc22	Loc24	LocD
Task4	0.6980	0.6986	0.0000	0.6986	0.0890	47.508	50.677	15.336	15.370	0.1597	0.1996	0.1946	64.155	88.484	86.731	86.694	53.348	24.474	15.377
Task6	22.134	30.742	25.674	35.025	40.971	77.111	79.030	62.095	62.334	50.093	50.420	43.186	82.864	95.086	94.352	94.327	80.343	65.459	61.552
Task8	53.353	58.501	55.316	61.058	64.446	86.414	87.342	77.131	77.286	70.036	70.146	65.855	89.644	96.475	96.015	95.995	90.191	78.753	76.921

Fig. 4. Server Utilizations of Different Information Quantity of Meters



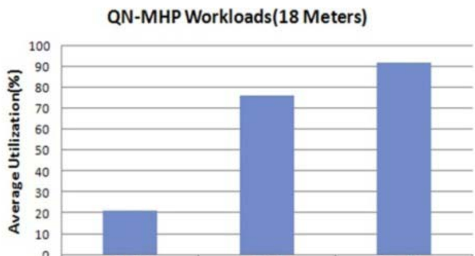
	Loc1	Loc2	Loc3	Loc4	LocA	LocB	LocC	LocE	LocG	LocF	LocH	LocV	LocW	LocX	LocY	LocZ	Loc22	Loc24	LocD
Task7	0.1633	0.1633	0	0.1633	0.02	23.32	23.283	3.55	3.55	0	0	0.04	54.18	77.993	77.98	77.967	32.777	21.357	3.5433
Task8	22.135	30.743	25.674	35.025	40.971	77.112	79.03	62.095	62.334	50.094	50.421	43.186	82.865	95.086	94.353	94.328	80.344	65.46	61.553
Task9	84.32	86.039	84.771	86.889	87.879	95.1	95.404	92.014	92.039	89.744	89.777	88.317	95.342	98.797	98.778	98.766	95.959	95.192	91.922

Fig. 5. Server Utilizations of Different Information Frequency of Meters



	Task4	Task6	Task8
%	28.9946	60.674	76.362

(a)



	Task7	Task8	Task9
%	21.055	76.362	91.95

(b)

Fig. 6. (a)Workloads of Different Quantity (b)Workloads of Different Frequency

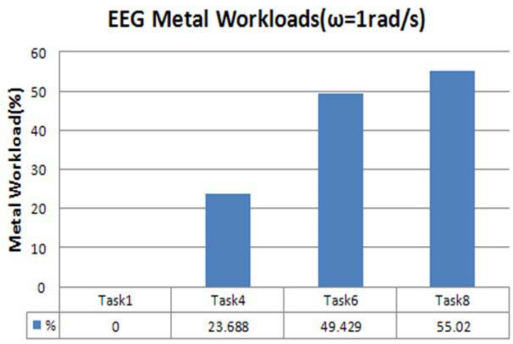
IV. EMPIRICAL VALIDATION

Brain wave of humans can be divided into δ wave (1 to 3 c/s),θ wave (4 to 7 c/s),α wave (8 to 13c/s),β wave (14 to 25 c/s),and γ wave (>25 c/s) [11]. Relevant research showed that α wave is most connected with the relaxed state, β wave increase when humans feel excited or cautious, while θ wave is closely connected with the state of oscitancy. Based on the above principle, we use the energy ratio of P θ/(P α + P beta) as the evaluation index of the mental workload. In this experiment, we chose 5 subjects aged from 20 to 30 years old, all in good health. The experiment process is shown in Fig.2.

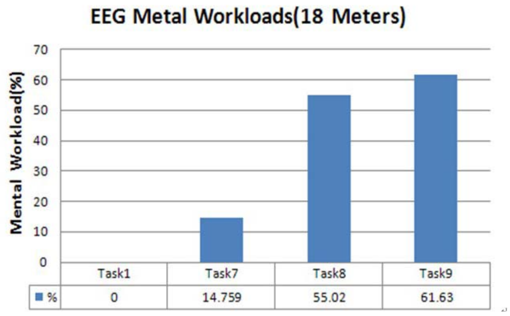
Set the energy ratio under task1 as zero reference, and subtract it from the ratio values of all the other tasks. Eq.1 represents as follows, EEG Metal Workload=Pi-P1, i= tasknumber, and

$$Pi = 10\lg(\mu v_i^2) \qquad (1)$$

Adjust the value range to be 0 to 1, and repeat the above-mentioned process to get the average data of 5 subjects. At a certain frequency of information, the mental workload gradually increase along with the quantity of information(Fig.7a); At a certain quantity of information, as the frequency of information increases, the mental workload also increases gradually(Fig.7b)

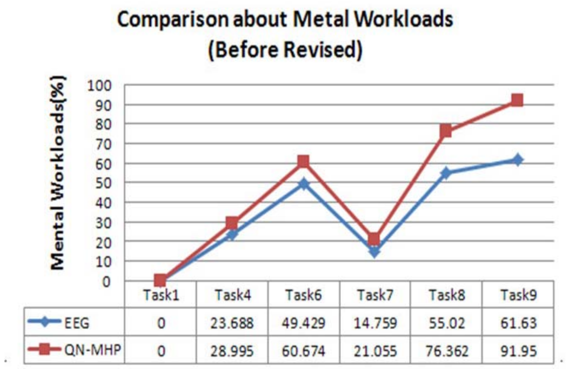


(a)

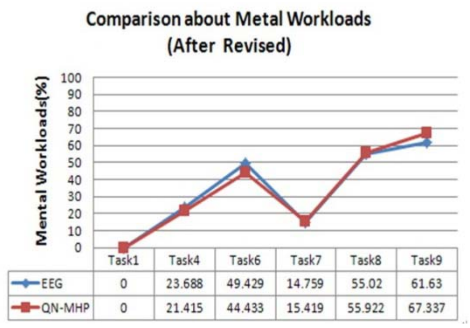


(b)

Fig. 7. (a)Workloads of Different Quantity.
(b)Workloads of DifferentFrequency



(a)



`(b)

Fig. 8. (a) Workloads Comparison (Before Revised)
(b) Workloads Comparison (After Revised)

Relative error: σ%=| （P1-P2） /P2|,where P1=Mental workload of QN-MHP,P2=Metal workload of EEG;Maximum error: calculate the relative errors of Task4,Task6,Task7,Task8 and Task9,we get Maximum error=Max {|-9.60%|, |-10.11%| , |4.47%|, |1.64%|, |9.26%|}=10.11%.

Compare the estimated values of QN-MHP with the measured EEG mental workload, we see that both of them conform well with the qualitative changes of mental workloads under different tasks, but the values of the formal are all greater than that of the later,Fig.8a shows. Taking the series values of the measured EEG mental workload as a reference, we make a parameters optimization of the original mode, according to the principle of minimum distance. Here we get the correction coefficient C =1.364, namely the workload value of the original model should be divided by C. After revised, the result comparison is shown in Fig.8b.

V. CONCLUSION

The QN - MHP model is checked based on the result of EEG test. After parameter correction according to the energy ratio of EEG signals, the revised QN - MHP model conforms well to the mental workloads under different tasks. This evaluation method cannot only avoid the dependence of experiments, but also the subjective error factors in the traditional validation method of NASA - TXL test scales, thus make the evaluation of mental workload more convenient, and the results more accurate.

ACKNOWLEDGMENT

This project was supported by the National Natural Scientific Foundation of China (Grant No.61075069).

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