Exam for “The Human Controller”, WB 2306
June 29, 2011

Instructions

You can write the answers to the following eight questions on separate sheets. Do not forget to write your name (with initials) and your study-number on those sheets. When answering the questions, you can use the written material that was put at your disposal during the course.
The ideal answer is well-motivated but clear, short and to-the-point. Note that writing down non-relevant information may work against you in judging your knowledge about the question. Each of the 8 questions is worth a full point for the final grade (and each sub-question 0.25 points, unless stated otherwise). Good luck!

Question 1

a) Explain in your own words what an observation window for a sensory system is, and sketch one for the auditory system (include values on the axes).

b) Explain the difference between the Just Noticeable Difference (JND) and the (upper and lower) boundaries of the observation window of the auditory system, and how each is measured.

c) Give reasonable estimates of the values for both the JND and perception boundaries of auditory signals. Use these values to motivate the signal properties of an auditory warning aimed to help drivers in the following cases:

   I. exceeding a speed limit

   II. an imminent crash with a lead vehicle

Note that question 1c) is worth 0.5 points.

Question 2

In tele-operated control, a human operator controls a robotic device in order to handle objects without being physically present.

a) Name three general situations in which tele-operation is necessary, and illustrate each by naming a relevant industrial application area.

b) Draw a block scheme of the human operator using a tele-operation system, showing the main components as blocks, naming the signals that represent the lines, and including available feedback loops (note that a system block needs to be added if feedback is not readily available to the human).

c) Suppose you are using the telemanipulator to precisely move a grasped object in the remote environment from point A to point B. Describe metrics for performance and control effort that show how well you are doing compared to other users.

d) Suppose the distance A to B is now 10 times smaller, as well as the grasped object. What could you do to improve the performance (without adding any additional hardware)? How would situations c) and d) compare then, using the metrics described earlier?

Question 3

Suppose you are steering a conventional car along a straight road, where you sometimes experience wind gusts.

a) Name three different cues from different senses that are used to help you to maintain your position in the lane you're driving in.

Recently the development of steer-by-wire systems has been given a lot of attention. These systems decouple the physical interaction between steering wheel and tyres, giving new possibilities to determine relationships between torques and positions.

b) Discuss technical possibilities and limitations (at least two of each) of this technology in light of their hypothesized impact on driving safety and comfort.

c) One of the options automotive researchers are investigating is to control the tyre angles by blending steering wheel inputs with autonomous inputs from a controller based on sensor information. Describe advantages and disadvantages of this system.

d) Suppose you are Dutch person on holidays in England for the first time, and have just rented a car that you are not familiar with. According to Rasmussen, which type(s) of behaviour would you have trouble with initially?

Question 4

In automotive research, new systems are considered to support the driver in steering., based on sensor information about the road ahead of you.

a) Draw three block schemes of a driver controlling a car with each of the three following support systems:

   a. an automation system controlling the position in the lane.
   b. a continuous lateral haptic guidance system
   c. binary haptic feedback that warns the driver when he/she is about to leave the lane.

   Please discuss which task(s) the human controller needs to perform, and which the support system.

b) Describe the benefits/limitations of each of the systems in relation to each other and to manual control; and how you would test your hypothesized benefits in an experiment (mention measured variables/metrics with which to quantify your hypotheses).

Note that questions a) and b) are each worth 0.5 points.

Question 5

Suppose that a human controller uses a joystick to control a critically unstable airplane in a computer simulation, with transfer function:

$$H_{crit}(\omega) = \frac{-\lambda}{\lambda - j\omega}$$

a) Explain in maximally 10 lines how mental load can be measured by using a critical instability system.

b) What will be the transfer function of the human controller when λ is very small?

c) Now suppose we ask the controller to keep an equally unstable joystick in the centre. Will it be easier or more difficult for the human controller to stabilize the joystick? Explain with metrics that would provide experimental evidence.

d) Are any of the two ways suitable for measuring the mental load of a pilot in a real plane? Explain why yes/no.

Question 6

Consider the following painting by Escher, a Dutch artist who was a master at illusions.

a) Name at least 5 depth perception cues that Escher uses in this painting. What other depth perception cues do we have available, in general?

b) Discuss how Escher tricks you into accepting this illusion, based on your knowledge of depth perception.

c) Which cue(s) mentioned in question a) would break Escher's illusion if a museum would like to make a real-world exhibit based on this painting?

d) In the Escher Museum in the Hague, you can reproduce the following picture of yourselves. Explain how this picture is made, knowing that both of the depicted persons are of roughly equal size, and that no photoshopping is used!

Question 7

A cherry picker consists of a long hydraulic arm on which a platform is placed. A human controller stands on the platform in front of a control panel with a **velocity joystick** by which he can control the movements of the platform. The relationship between the deflection of the joystick and the desired position of the platform is equal to:

desired position platform $= k_1/(j\omega)$ *. deflection velocity joystick*

in which k_1 is a constant factor. The hydraulic arm is long and shows flexible, undamped behaviour. The relationship between the desired position of the platform and the real position of the platform is therefore equal to:

real position platform $= 1/(k_2 (j\omega)^2 + 1)$ *. desired position platform*

in which k_2 is a constant factor.

a) Draw a block scheme of the human controller in the control loop when controlling the platform.
b) Is the human controller able to control the real position of the platform with the velocity joystick? Explain why yes/no.

Suppose that the velocity joystick is replaced by an **acceleration joystick**. The relationship between the deflection of this joystick and the desired position of the platform is equal to:

desired position platform $= k_3/((j\omega)^2)$*. deflection acceleration joystick*

in which k_3 is a constant factor.

c) Is the human controller able to control the real position of the platform with the acceleration joystick? Explain why yes/no.

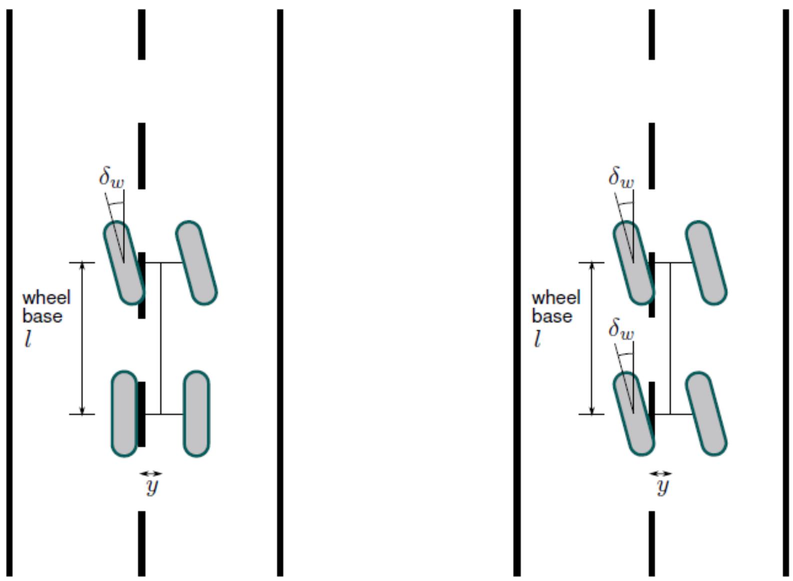
Suppose that another hydraulic arm is used that is completely stiff. The relationship between the real position of the platform and the desired position of the platform is then equal to:

real position platform = desired position platform

d) Is the human controller now able to control the real position of the platform with the **acceleration joystick**? Explain why yes/no. If yes: give the transfer function of the human controller.

Question 8

Normally, cars are steered with front wheels only (left part of the figure). But advances in technology have stimulated car manufacturers to explore steering on all four wheels. At high speed, lane change maneuvers with such a system can be performed by turning both the front and rear wheels into the direction of the lane change (right part of the figure).



For this question, assume that the lane change maneuver with such a car is performed by deflecting all wheels with an equal amount; i.e. the car is purely moving sideways in addition to its forward motion*. Furthermore, consider that steering wheel and heading (with respect to the road heading) angles are small, and that the cosine or sine of these angles can be approximated by the angle itself.

a) Assuming that tyre dynamics can be neglected, give the transfer function for the lateral position y in response to a steering wheel input δ_w for a conventional car driving with a contant speed V. What is the order of this transfer function?

b) Assuming the car driver could only observe the lateral position with respect to the road, y, what could be the type of equalization selected according to McRuer's simplified precision model?

c) Discuss how human control will deviate from the assumption above if the human operator can select any feature from the visual field in front of him/her.

d) Again, assuming that tyre dynamics can be neglected, give the transfer function for the lateral position y in response to a steering wheel input δ_w of the car with the proposed four-wheel steering. What is the order of this second transfer function?

e) What would now be the type of equalization selected according to McRuer's simplified precision model?

** Note that since you can't make turns with the proposed set-up, in reality the rear steering wheel angle will not be fully equal to the front wheel steering angle. Also, the steering ratios will be velocity dependent, so that at low speeds the vehicle can make a shorter turn, and at high speed the vehicle can make sideways movements.*