ESTIMATION OF THE DIFFERENCE IN VISUAL LATENCY IN THE PULFRICH EFFECT

Attention! The text presented below is by no means enough to prepare for the practical. Please refer to recommended literature.

Applied methods

The aim of this practical is to estimate the difference in a visual latency due to application of the filter. The estimation will be done for three different permeabilities of the filter for the classical (linear) and the rotational Pulfrich effect. The idea of the classical Pulfrich effect is depicted in the Figure 2. It is worthy to note that the magnitude of this difference is not more than few milliseconds!

1. *Linear Pulfrich effect.*

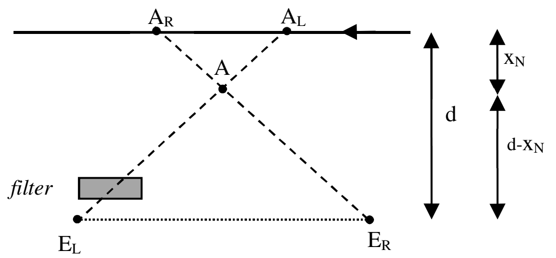

Figure. 6 *A scheme of relationship between the difference in a visual latency and the distance between the near point and the actual trajectory, x_N.*

In this part of the practical positions of the near point and the far point of the seeming movement of a pendulum will be estimated (see Figure 1). Knowing the distance between any of these points and the actual trajectory of movement, velocity of pendulum's movement, distance between pupils of eyeballs of the watching student and distance between the watching student and the actual trajectory of movement, we can calculate the difference in a visual latency due to application of the filter.

Let's consider a situation where the left eye of the watching student is covered by the filter and the pendulum is moving to the left, such as it is shown in Figure 6. When the pendulum is passing seemingly the near point (A), it is recognised by the right eye in the point A_R, whereas by the left eye, due to increase in the latency caused by the filter, in the previous position A_L. Time needed by the pendulum to move from the point A_L to the point A_R is equal to the difference in a visual latency due to application of the filter, Δt. Thus, we have:

$$|A_L A_R| = v\ \Delta t \tag{1}$$

where: v – velocity of pendulum's movement, $|A_L A_R|$ - distance between the points A_L and A_R. Distance between the left eye (E_L) and the right eye (E_R) is measured as the distance between pupils of both eyeballs of the watching student and is named as the "b" parameter. Taking into account that the triangles A_RAA_L and E_LAE_R are homothetic and taking the equation (1), we can obtain the following formula:

$$\frac{v\,\Delta t}{x_N} = \frac{b}{d - x_N} \qquad (2)$$

where: x_N is distance between the near point and the actual trajectory, d stands for distance between the watching student and the actual trajectory. The final formula is given below:

$$\boxed{\Delta t = \frac{b}{v}\frac{x_N}{d - x_N}} \qquad (3)$$

The difference in a visual latency due to application of the filter can also be estimated as a function of distance between the far point and the actual trajectory x_F (see Figure 7). Since the triangles $A_L A A_R$ and $E_L A E_R$ are homothetic and taking into account the equation (1) the following formula is obtained:

$$\frac{v\,\Delta t}{x_F} = \frac{b}{d + x_F} \qquad (4)$$

And the final formula is :

$$\boxed{\Delta t = \frac{b}{v}\frac{x_F}{d + x_F}} \qquad (5)$$

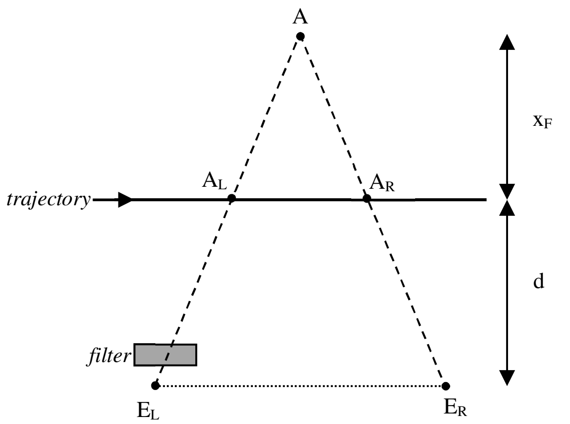

Figure. 7 *A scheme of relationship between the difference in a visual latency and the distance between the far point and the actual trajectory, x_F.*

The equations (3) and (5) were first introduced by A. Lit. Experimental practice has shown that the calculated values of x_N and x_F may be significantly different from each other (although both of them refer to the same physical parameter Δt).

It should be taken into account that the proportion is not preserved in Figures 6 and 7. In reality the "d" distance is at least 10 times longer than the distances x_N and x_F. This distance is more than 100 times longer than the distance between the points A_L and A_R, the latter is no more than a few millimetres.

2. *Rotational Pulfrich effect (observing a vertical rod on a rotating disk).*

In this part of the practical a rotational movement of a vertical rod attached to a disk, after having covered one eye of the watching student by a filter, is observed. The frequency of rotations is increased until the "transition value" is obtained, where it seems to the watching student that the rod is moving "back and forth" through the centre of the disk. If it is difficult to recognise such a situation the frequency is increased until it seems to the watching student that the rod is moving in the opposite direction. The measured parameters are: the time period of rotations that corresponds to the "transition value" of the frequency and distance between the watching student and the centre of the disk. After having obtained both parameters and taking into account the distance between pupils of eyeballs of the watching student (the "b" parameter) measured in the previous section, we can calculate the difference in a visual latency.

E_L E_R

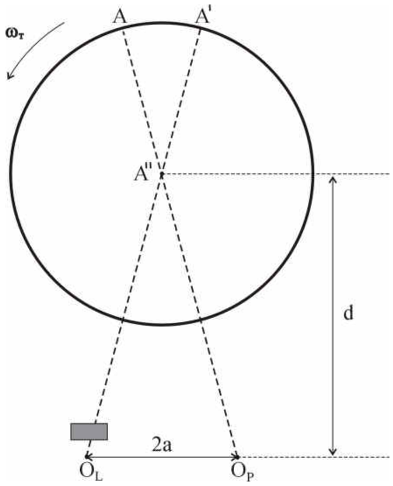

Figure 8. *A scheme of relationship between the difference in a visual latency and the "transition" frequency.*

Let's consider the above-mentioned „transition" frequency, where the rod is moving seemingly through the centre of the disk. Such a situation, where the left eye is covered by the filter and the disk is rotating counter clockwise, is depicted in Figure 8. The point A in the figure corresponds to the „present" position of the rod (recognised by the right eye), whereas the point A′ refers to its "past" position (recognised by the left eye), in such a situation the seeming position of the rod will be the point A″. The difference in a visual latency, Δt, is equal to the time needed by the rod to move from the point A′ to the point A.[1] Taking into account the definition of an angular velocity:

$$\omega_T = \frac{\angle AA''A'}{\Delta t} \tag{6}$$

where: ω_T is the angular velocity corresponding to the „transition" frequency and the angle AA″A′ is measured in a circular measure.

Taking into account the trigonometry we obtain the following formula:

$$\mathrm{tg}\left(\frac{\angle E_L A'' E_R}{2}\right) = \frac{a}{d} \tag{7}$$

where: a is a half the distance between pupils of eyeballs of the watching student (half of the "b" parameter), d is the distance between the watching student and the centre of the disk, whereas the angle $E_LA''E_R$ is measured in a circular measure. On the basis of the equation (7) the following formula can be introduced:

$$\mathrm{arctg}\frac{\mathrm{a}}{\mathrm{d}} = \frac{\angle E_L A'' E_R}{2} \tag{8}$$

where arctg is a function, which is reciprocal to the function tangent (so called "arcus tangent"). Since the angles AA″A′ and $E_LA''E_L$ are equal to each other, one can re-arrange the equations (6) and (8) to the final form:

$$\omega_T \Delta t = 2\,\mathrm{arctg}\frac{\mathrm{a}}{\mathrm{d}} \tag{9}$$

For small values of x we can assume that arctg x ≈ x, whereas the angular velocity ω_T can be presented by other formula:

$$\omega_T = \frac{2\pi}{T} \tag{10}$$

where T is the time period of rotations that corresponds to the "transition value" of the frequency. Taking additionally into account that the distance between pupils of eyeballs of the watching student

[1] *The difference in a visual latency remains unchanged even if the distance between the watching student and the centre of the disk is changed. However, the "transition" frequency is diminished when the distance is increased and increased when the distance is diminished.*

(the “b” parameter) is equal to 2a, we finally obtain, after simple re-arrangements, the formula:

$$\boxed{\Delta t = \frac{T}{2\pi}\frac{b}{d}} \tag{11}$$

The equation (11) was first introduced by D. Nickalls.

Required knowledge:

1. Binocular vision: fixation, retinal correspondence, retinal disparity. Horopter. Sensor fusion, Panum’s fusional area.
2. Idea of the Pulfrich effect (see theoretical supplement).
3. Experimental methods applied in the practical (see theoretical supplement).