

Alternative Computer Cursor Shifts for Large Amplitude Eyesight Jumps

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Introduction

Today among the tools in the human and computer interaction (HCI), mouse and the keyboard are the primary input devices. Recently, eye-gaze aware interfaces, based on eye tracker as an input device, have been gaining popularity in the HCI community [1, 2].

Oculomotor system, being important part of the vision, has exclusively important features. There are no other parts of the body than eye, which has so well developed sensor and motor subsystems in one. Sensors of the eye, scanning in the user's interface field, found an object of interest and muscles of the eye ball turn the gaze to the direction until image of the object falls on the fovea, which is most sensitive part of the retina. Accuracy and large velocity of eye movements brings to the idea to use visual system not only traditionally to accept visual information but, measuring position of the gaze, to perform control commands. Most common tasks for the oculomotor system are to determine coordinates of the object of interest (target acquisition and pointing) and to write texts (typing) [3].

The majority of the HCI systems use fixation duration, which is called dwell time and used as a "click" to trigger the interface actions. Fixation-based selection necessitates data buffering, and therefore, introduces a delay in the performance of the action. Due to high velocity saccades seem to be the most appropriate eye movements, which could be used to replace the "click" command.

Many limitations exist to use the gaze pointing as a command for computer action. Actually eye movements help vision to get most important information from the surrounding and unnatural task to select the target overload the perceptual function. Fixational micro-movements [4] and other not coordinated eye movements interrupt strict gaze pointing. We therefore propose an alternative approach – to use the cursor pointing only for large gaze shifts. With such an approach, gaze pointing appears to the user only to replace large amplitude manual cursor shifts.

There are a few compelling reasons to motivate such an application. First of all, "what you look at is what you get" [5] is captivating natural feature of our vision and no

other input method can act as quickly. Second, using alternative computer cursor shifts for a large amplitude gaze jumps, let hands to be occupied with other tasks and reduces a fatigue. This feature is more attractive for portable computers with touch-pad, when possibility to use a mouse is limited. And third, eye tracking technology achieved great promotion solving the problem to find eyesight point on the computer screen [6] by using simple web cameras.

Saccadic eye movements

Saccades are fast, dart-like, conjugate eye movements used to position the fovea of the eyes in a time optimal manner [7, 8]. They could be categorized into refixation saccades and microsaccades, which are seen only during fixation. Normometric saccadic refixations could be either single-step or multi-step movements. Multi-step (usually double-step) saccades are executed in two-steps: primary and corrective saccades. Primary saccade could be too small (hypometric) and too large (hypermetric) with respect to the intended target position. Only 30 % of saccades are single-step and precisely reaches new target. From the rest of the multi-step saccades only 30 % are hypermetric. Normometric saccades demonstrate pretty common trajectories. Saccadic latency, or reaction time, typically refers to the time from onset of the non-predictable step of target movement to onset of the saccadic eye movement initiated to foveate the displaced target. It is approximately 180 to 200 msec, with standard deviation 30 msec. Relationship between peak velocity and amplitude of the saccade, called the main sequence, typically separate these movements from other limb or head movements. Main sequence illustrate that peak velocity is 310 deg/sec for 10 deg amplitude of the saccade, 450 deg/sec for 15 deg amplitude and 500 deg/sec for 20 deg amplitude.

The algorithm of the alternative control of computer cursor

Our key idea is to use a gaze to redefine the position of the computer cursor to be at the vicinity of the user's

place of interest. At that situation, we can see two options: first, passive option, when user shifts his gaze only with the purpose to get new information (for example, to read the text) and the second, active case, when user wants to elicit command by doing some manual action (perform a command or write). In the first, passive case, only for reading option, it is not necessary to redefine cursor to the eyesight place because cursor being in the operational visual field could disturb the vision. During the active case, because the cursor must be used for action, it is necessary to bring it to the new place of interest what the user is looking at. Separation of these two options could be a manual action performed by the touch-pad or computer mouse. Once the position of the computer cursor had been redefined, manual control returns back to the user. Now user is able to continue working as usual and small amplitude gaze shifts did not activate alternative control of the cursor

It is obvious that the most important parameter is the size of the deactivation area A , shown in the Fig. 1, overrun of which by the eyesight of the user activates alternative cursor control. This area is defined by the amplitudes of the quick gaze shifts in the horizontal and vertical directions A_x , and A_y , respectively. Square A_x , A_y in the Fig.1, also could be named as an operational visual field (OF) and this field moves together with the current gaze position of the user. For better selection, not only amplitude of the eyesight shift but also velocities of the eye jump in the vertical and horizontal directions V_x and V_y respectively, are used to define the threshold of the activation of the alternative cursor control. This means that quick eye jumps with threshold amplitudes A_T , bigger than

$$A_T = \sqrt{A_x^2 + A_y^2} \quad (1)$$

and transient velocities V_T , bigger than

$$V_T = \sqrt{V_x^2 + V_y^2} \quad (2)$$

prepare the program of the alternative cursor control for cursor shifts. In the paper [1] threshold area is defined as circle with the radius of 120 pixels.

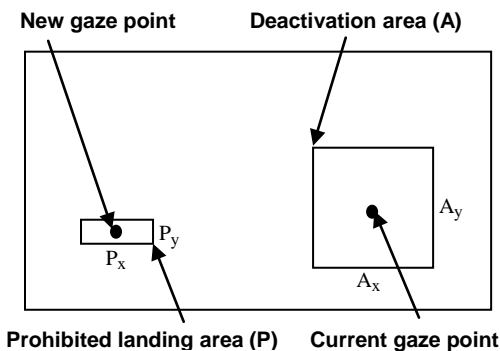


Fig. 1. Area of the deactivation of the alternative cursor control (A) and prohibited area for cursor landing (P) in the computer screen

Second important parameter of the alternative cursor pointing method is the size of the area P, in which landing of the cursor is prohibited. At first, it seems that high

accuracy of the positioning after the redirection of the cursor to the point of the eyesight (target) is desirable. But, with the purpose not to cover the text or picture, better decision is to place a cursor in the vicinity of the target and let the user to continue further operation using manual input. By the opinion of the authors, the size of the prohibited landing area P could be chosen as the distance between two vertical spacing lines P_y and twice bigger in the horizontal direction $P_x=2P_y$.

The algorithm of the alternative cursor control is illustrated in Fig. 2. Our developed computer program runs an infinite loop in background. First, the data at the sampling frequency 120 Hz is taken from eyesight tracker. Alterable number L of these gaze points (horizontal and vertical coordinates G_H and G_V) are averaged and stored in the circular history buffer, in which values are memorized during 0.5s time interval. Gaze velocity V_G is obtained as a difference between two gaze point values obtained at the current time and at the time interval Δt before. Time interval Δt also is defined as the parameter of the algorithm. Later, transient gaze velocity V_G is compared with the threshold value of the gaze velocity V_T . Instead of the threshold value of gaze (eye) velocity V_G , the threshold value of the gaze acceleration A_G could be calculated and compared with the current gaze movement acceleration A_T . If the calculated values of the gaze velocity or gaze acceleration are exceeded by the current values, cursor is repositioned near the current gaze point, ensuring, that it does not land in the prohibited zone P. If active mode is being used, the reposition of the cursor occurs only after the mouse has been moved. Program allows the correction routine, which enables the reposition of the cursor second time after alterable time interval T_K . This can be used to adjust position of the cursor after corrective saccades. Inactivity time T_I , during which repositioning of the cursor is disabled also could be implemented. This option let us after the first reposition of the cursor, during time interval of 500 ms, inactivate second repositioning.

Optimization and set of the parameters of algorithm

With the purpose to find optimal parameters of the algorithm, experimental investigation of the alternative computer cursor was performed. Movements of both eyes were recorded with eye tracker *EyeGaze System* produced by *LC Technologies Ltd*. Healthy subjects, 20–53 years old, were recruited after informed consent. Among the five subjects, two authors participated in the experiments. None of the subjects showed any visual or oculomotor pathology other than refraction anomaly. Subjects had normal or corrected-to-normal visual acuity.

Subjects were asked to execute four computer tasks with traditional PC mouse and cursor controlled by gaze. These experiments were: to open and to close nine prepared points (1), to direct the picture over the in advance prepared points (2), to direct the cursor to the targets appearing in the non-predictable positions (3), to correct the mistakes in the text (4). During these experiments, different sets of the parameters were used and task fulfillment time (1, 2, 4) or score (3) was measured. The values of optimal parameters were defined and placed in

Table 1. They were selected for the further investigation of the effectiveness of the alternative cursor control.

Table 1. Values of the optimal parameters of the algorithm

Parameter	L	Δt , ms	V_T , m/s	A_T , m/s ²	T_K , ms	T_I , ms
Value	1	8.3	0.24	0.12	40	500

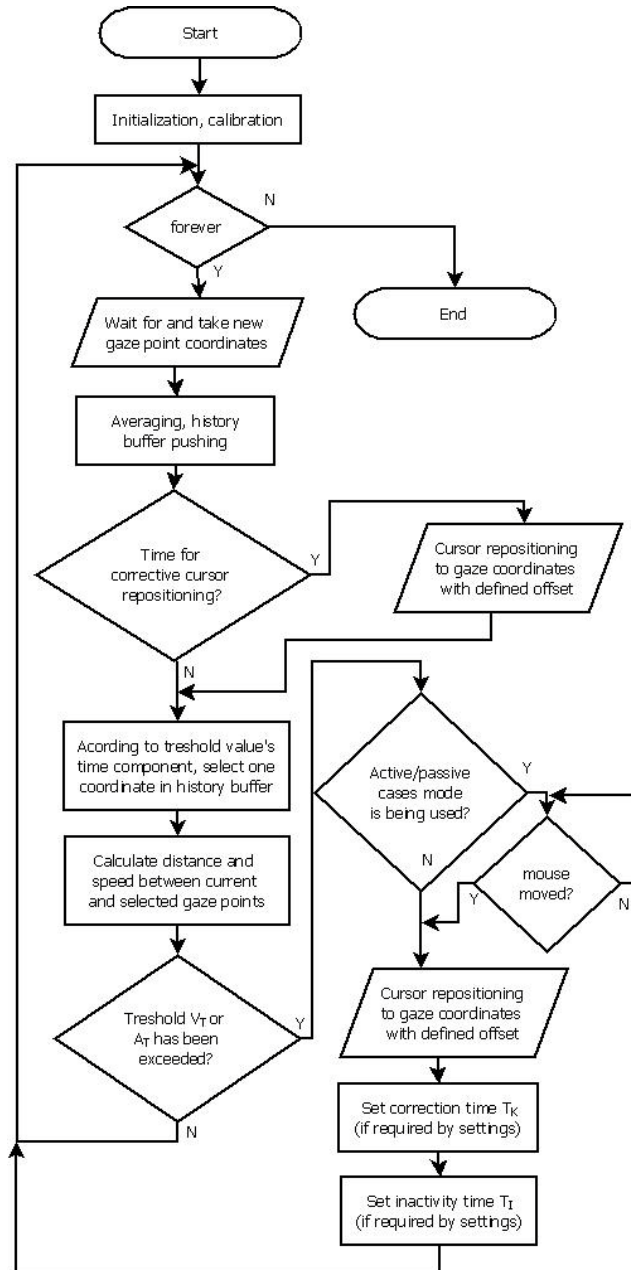


Fig. 2. Algorithm of the alternative control of the computer cursor

Investigation of the effectiveness of the alternative cursor control

The effectiveness of the alternative cursor control comparing with the traditional mouse was investigated during execution of the earlier described four experiments. Obtained results are illustrated in Fig. 3. They show that alternative control of the computer cursor most effective is for directing the cursor to the targets (3) appearing in the non-predictable positions. In this case effectiveness

exceeds 40 %. Second experiment, which shows effectiveness of 20 %, is opening and closing new programs (1). Picture drawing (2) over the prepared points did not reveal the advantage of the method of the alternative cursor control. The computer task of the correction of the mistakes in the text (4) revealed that results obtained with mouse are better.

Obtained experimental results illustrate that alternative method of the computer cursor control let us get advantage during execution of the computer tasks, when large cursor shifts are dominating (experiments 1, 3). During computer tasks, when the largest part of the job must be done by small amplitude cursor shifts (text correction) and keyboard, used to pick up the right letters, alternative control of the computer cursor is not effective.

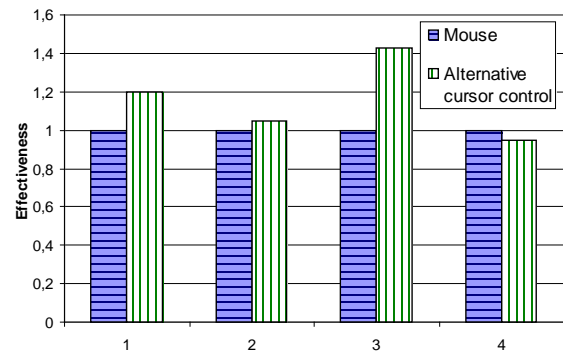


Fig. 3. The results of the effectiveness of alternative control of the computer cursor for four different computer tasks: 1, 2, 3, 4

It is necessary to point out that deactivation area is not defined by the parameters of the algorithm. The size of the deactivation area A_X , A_Y is defined indirectly setting the threshold of peak velocity of eye jump V_T . Main sequence or strict relationship between the peak eye velocity and amplitude of eye jump indicate that, when threshold of the peak velocity is $V_T=0.24$ m/s (200 deg/s), amplitude of the eye jump is more than 36 mm (3 deg).

Implementation of the modes of correction time T_K and inactivity time T_I in the algorithm did not revealed substantial positive features of the new method and were not used.

Investigation of the active and passive modes of alternative control of the computer cursor revealed that there is no large difference of the effectiveness of the new method. In some computer tasks more convenient is active mode, for example reading and drawing, when not many input commands are executed. During passive mode, due to prohibited area, computer cursor is landing below the gaze point and did not disturb the vision.

Alternative control of the computer cursor is based on the eyesight direction of the user therefore during the first experiments this paradigm is not comfortable for them. Better results of the effectiveness in the range of 20 – 50 % of new method could be obtained for trained subjects and the concentration of attention.

During our experimental investigation, interesting psychological phenomena was observed. First, during experiments with alternative control, when computer cursor appears in the new position, towards which eyesight is directed, for subjects it seems pretty natural. Second,

when, after experimental session, alternative control of the computer cursor was switched off, subjects had a feeling that computer cursor from one point to another moves too slow.

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V. Laurutis, S. Niauronis, R. Zemblys. Alternative Computer Cursor Shifts for Large Amplitude Eyesight Jumps // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 9(105). – P. 61–64.

The purpose of this research was to investigate alternative control of the computer cursor based on the application of large amplitude gaze shifts of the user. Instead of manual control, proposed algorithm redefines cursor to the new place on the computer screen, where eyesight of the user is directed. Amplitude and velocity of the saccadic eye movement of the user are used as input parameters for cursor redirection. Two options of the redirection of computer cursor: passive and active were investigated. During passive option, used for reading only, computer cursor is ready to appear in the new place onto computer screen but is not activated (not shows up) with the purpose not to disturb the vision. During passive mode, supplement manual input signal is used to activate computer cursor in the new position onto the screen. During active mode, computer cursor is always activated in the position, where eyesight of the user is directed. Experimental investigation of the new alternative method of cursor control was performed using eye tracker *EyeGaze System* produced by *LC Technologies Ltd.* and program, developed in our laboratory. The parameters of the program were optimized in the most comfortable way for the user. Effectiveness of the alternative cursor control during real visuo-motor tasks was investigated. III. 3, bibl. 8, tabl. 1 (in English; abstracts in English and Lithuanian).

V. Laurutis, S. Niauronis, R. Zemblys. Alternatyvus kompiuterio žymeklio perkėlimas esant didelės amplitudės žvilgsnio šuoliams // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 9(105). – P. 61–64.

Šio tyrimo tikslas – ištirti alternatyvų kompiuterio žymeklio valdymą, naudojant didelės amplitudės vartotojo žiūros linijos šuolius. Vietoj žymeklio valdymo vien tik ranka pasiūlytas algoritmas, perkeliantis žymeklį į naują vietą kompiuterio ekrane, kur yra nukreiptas vartotojo žvilgsnis. Kompiuterio žymekliui perkelti kaip įėjimo parametrai naudojami vartotojo sakadinių akių judesių amplitudė ir greitis. Buvo ištirtos dvi žymeklio valdymo galimybės: pasyvi ir aktyvi. Esant pasyviai režimui, kuris naudojamas tik tekstui skaityti, kompiuterio žymeklis yra pasirengęs atsirasti naujoje ekrano vietoje, tačiau tam, kad netrukdytų regai, jis nėra aktyvinamas. Žymekliui aktyvinti, dirbant pasyviuoju režimu, būtina papildoma rankinio valdymo komanda – pirminis postūmis kompiuterio pele. Dirbant aktyviuoju režimu, žymeklis naujoje ekrano vietoje, ten, kur nukreiptas vartotojo žvilgsnis, aktyvinasi savaime. Naujojo alternatyvaus metodo eksperimentiniai tyrimai buvo atlikti naudojant *LC Technologies* kompanijos pagamintą *EyeGaze System* akių judesių registravimo įtaisą ir mūsų laboratorijoje sukurtą programą. Programos parametrai buvo optimizuoti taip, kad jie būtų patogūs vartotojui. Alternatyvaus žymeklio valdymo efektyvumas buvo ištirtas atliekant realias regėjimo ir motorinės kontrolės užduotis. II. 3, bibl. 8, lent. 1 (anglų kalba; santraukos anglų ir lietuvių k.).

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