

Highly Flexible Software for Gaze Path Analysis and Visualization

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Introduction

The growing interest in using eye-movements for human-computer interaction has also increased the need for tools to investigate and analyse the behavior of human eyes [1]. First such tools were developed around the same time when the first eye trackers became available. However, these tools were bound to the structure of data produced by a specific eye tracker, and thus each tool supported only the eye tracker for which it was developed. This hampered introduction of next-generation devices and required a lot of effort to transfer the functionality of the tools developed to new platforms.

Nowadays, there are many commercial and academic products available for researchers in this field and the quality and accuracy of eye-tracking devices are constantly increasing. Several researchers have attempted developing tools for supporting analysis of the data recorded with different eye trackers [2, 3]. This way the same software could support different data protocols and formats. Meanwhile, several manufactures released eye trackers having protocols for data transfer and collection that can be recognized by some most intelligent and advanced gaze-data analysis tools.

However, there is still a lack of effective tools to support various eye trackers in recording eye movements and using this data in real time. Despite the numerous methods developed for analysing and visualizing gaze paths, no universal tools are available yet to accomplish this.

To fill in this gap, we developed iComponent – a software product with a highly flexible architecture for easy development of interchangeable plug-in modules to support various eye-tracking devices and experimental software.

This paper describes the main functionality of iComponent related to gathering, analysis and visualization of eye gaze data.

The presentation is organized in the following sequence. First, the login manager is introduced. Then, the paper describes the Quick Start wizard used to help the user prepare for a data recording or analysis session. Finally, details are given on the main interface elements and interaction options available to the user.

Login Manager

When iComponent starts, the *Profile Manager* appears to select a profile (Fig. 1).



Fig. 1. Profile manager

A user is supposed to select one of the existing profiles or create a new one using appropriate buttons. Obviously, it is not possible to create a profile of an existing name. There is still possibility to exit the application, pressing button *Exit*. Even though iComponent supports all functionality without profiling, its current version restricts execution without logging in as a profiled user. A profile can be password-protected. Users may enter a password in a profile creation dialog (Fig. 2).

If they left it blank, the profile leaves unprotected. After the protected profile was selected in the profiles manager, the application will ask for the password. Passwords are storing encrypted with using one-way encryption algorithm in the *psw* file in the profile's folder. The encryption algorithm produces a code even for the

empty password, thus each profile has this file. If the password file is not in the profile folder, the application terminates execution.



Fig. 2. Dialog box for creating new profile

However, this protection is not strong since iComponent do not encrypt recording's data, so it is possible to view the data collected by other users. On the other hand, if a user forgets his/her password, the data is not lost and it is always possible to create a new profile and continue using this data. In the future, users will get possibility to encrypt their data if it must be unreadable for others simply turning on a flag that indicates an encryption.

After a profile was created, the application creates the folder of the same name in the folder *Profiles* and copies the iComponent file with default settings into this folder, so after log in iComponent has own customized user settings. The folder stores profile-relevant data, such as study projects, experiment options and gaze data files. The profile name is shown in the iComponent main window title as well as in titles of some other dialog.

Quick Start Wizard

The settings of a newly created profile have the flag that corresponds to the *Quick start* wizard execution after start up turned on. The *Quick start* wizard allows for novices easily to get started with the iComponent. After the successful login, this wizard shows its dialog immediately (Fig. 3).



Fig. 3. Choosing session to run

A user may use the contextual help to explore the meaning of the items in the list. The items *Recording*, *Visualization* and *Comparison* represent iComponent sessions. In the session *Recording* a user may load an

iComponent experimental plug-in (to show images, play video, type by eyes and so on), make preparations for eye data recording and then collect eye data to files and/or use eye movements in real-time to interact with a computer. Sessions *Visualization* and *Comparison* are quite similar in sense that both sessions provide tools to visualize eye movements, collected during session *Recording*. However, the session *Visualization* has a bit more visualization tools, but the session *Comparison* allows loading and visualizing several recordings at the same time.

After the session was chosen, the next dialog of the *Quick start* wizard to appear depends on the session selected.

Session Recording. After this session was chosen in the *Quick Start* dialog, the dialog *Study manager* appears next (Fig. 4). Nevertheless it is possible to run experiment outside of any study simply selecting it from the menu *Experiments*, it is recommended for novices to use conduct experiments using study profile. Studies help to organize recordings and to keep the same session and experiment settings during the same recording.



Fig. 4. Study manager

The manager allows creating and deleting a study as well as to set its options (left panel on the figure). The individual recordings of a study may be deleted as well (right panel of the figure). When a study is selected in the list, the name of experiment plug-in associated with the study selected is displayed below the list. The list of studies always has an item called *All studies*, which has no any plug-in associated and serves only to observe all recording made by all studies. Any recording can be deleted by selecting it and pressing the button *Delete recording*.

When a user pressed the button *New...*, the application asks for the name of the new study. After a user enters the name, the next dialog appears. Now the user may choose an experiment plug-in for the study (Fig. 5).

After an experiment is chosen, a dialog with the experiment's settings appears. This dialog is experiment-oriented and it resist in the same library as the experiment body. Users may adjust experiment settings and save it into the study settings file in the profile folder, pressing *OK* button. Note that users do not need to set experiments

settings again when selecting a study since the study settings file includes experiment's settings.

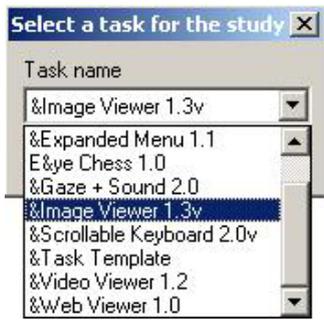


Fig. 5. Experiment plug-in selection for study

The screen recorder developed by TechSmith (Camtasia Screen Recorder) is integrated into iComponent core, so the application can record whole screen into AVI file during experiment and then use it during replay. The recorder SDK is freeware and distributed as ActiveX library. For studies that involve images, web pages or video observations using iComponent experiment plug-ins it is recommended to turn screen recording off since it noticeably increases PC processor workload and may disturb for experiment. The options of the screen recorder may be adjusted in a dialog (Fig. 6), which can be opened by pressing the button *Screen cam options...* in recording options dialog.

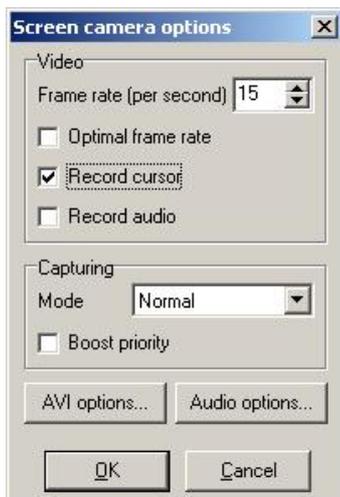


Fig. 6. Screen recorder options

In this dialog box, users may set screen capturing frame rate either to their own value or leave it to be optimized by the screen recorder. Captured video may include mouse cursor movements and sound. Camtasia Screen Recorder has 2 modes to be used during capturing: it is either *Normal* mode for usual capturing or *Quick* mode for capturing frames when something changes on the screen only. By default, the mode is *Normal*, but using *Quick* mode may greatly reduce the processor workload.

Session Visualization. After this session was chosen in the *Quick Start* dialog, the dialog *Open recording* appears next (Fig. 7). The left dialog's panel contains

names of studies created using this profile. When a user selects a study name, all recording made during this study become visible in the right dialog panel. One of the items in studies' panel is *All studies*. If this item is selected, the right field contains all recording from all studies.



Fig. 7. Dialog *Open Recording* for data selection to load

Session Comparison. After this session was chosen in the *Quick Start* dialog, the dialog *Data manager* appears next.

To add a recording, users have to press the button *Add...* and choose a folder with recording files. The results of searching appear in the list shown on Fig. 8. Users may unselect recordings they do not want to load or cancel the whole operation.

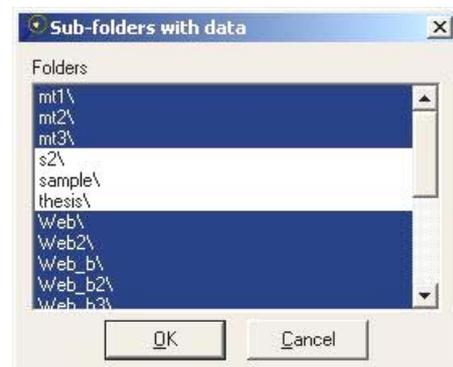


Fig. 8. Results of search for eye data recordings

If data was loaded successfully, it is marked as enabled and gets a predefined color. The button *Close*, which closes the manager and accepts the changes made, is enabled only if the list of recordings is empty or contains at least 2 recordings. User may remove any or all recording from the list, save or load the list of recording. A file with a list of recording has the extension *edl*. The format of this file (in ASCII) is very simple – each row contains a) the enabling flag (1 – enabled, 0 – disabled), 2) the assigned color (24-bit RGB value) and 3) the recording folder.

Recording

To prepare for a recording, a user has to switch to the session *Recording* and be sure that the proper driver is already selected. The name of the driver appears in the title of the iComponent main window, which includes also the loaded profile and session names (for example, “iComponent – Oleg: Recording by Tobii”). The driver may be changed in the *Driver Chooser* dialog that can be opened through menu item *Choose driver...* in the menu *Recording* (Fig. 9). This menu is available only during this session.

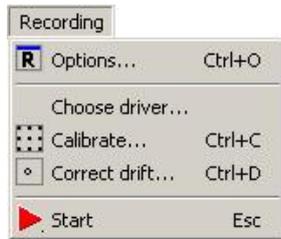


Fig. 9. Menu *Recording*

Next, users may either create a new study in *Study Manager* to select study experiment plug-in and adjust its options as well as recording option that will appear automatically, or complete these steps manually selecting an experiment and opening its options dialog in the menu *Experiments*.

After the actions described above, the software is ready to receive data. Users have to calibrate the eye tracker for a subject, using the menu item *Calibrate...* and then start the recording by pressing the menu item *Start*. The keyboard shortcut *Escape* is assigned to execute this function as well and might be more convenient than using menu. The same menu item and shortcut stops the recording. If eye tracker supports drift correction, users may execute it using menu item *Correct drift...* before the actual recording.

Visualizations

The visualizations are implemented as “views”. A view represents a conceptual model of a particular visualization. iComponent builds 4 views: 1) classic, 2) heat-map, 3) clustering and 4) replay. Only one view can be visualized at a time. Each of visualizations, with exception of the *Replay*, can present a single recording or several at once. All visualizations are available only in *Visualization* and *Comparison* iComponent sessions. The 1D graph with X-Y and pupil size changes in time appears in a separate window and may contain one or several recordings data.

Session Visualization. To build any visualization, a trial data must be loaded into memory first. Users may load data using *Load...* menu item from the menu *Visualizations* (Fig. 10).

This menu item opens the dialog *Open recording* described above (Fig. 7). When recording is loaded, the caption of iComponent window contains path to its folder.

The same menu contains the item *Save as...* to save the recording in the same (overwrite) or a new folder. If flag *Binary* is checked, the format of recording files will be binary, otherwise it will be in ASCII format. The button *Create new folder...* lets to create a new folder directly from this dialog.

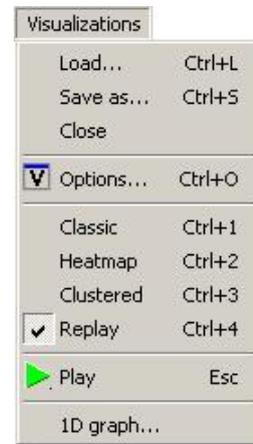


Fig. 10. Menu *Visualizations*

Classic visualization. In iComponent both data representations – scan-path and fixations-saccades chain – are available for analysis (Fig. 11).



Fig. 11. 2D eye movements plot

Fixation circles contain a small dot in its centers. Each line starts from the center of previous circle (with the exception of the first line) and ends at the center of the next one. Samples are brought out in colors by the dependency from gazing events they belong to.

The view allows quick access to gaze data through popup tips. When the mouse cursor moves upon a visualization object, the cursor changes its shape and a tip with the most relevant information about the underlying object appears close to it (Fig. 12).

Left Fixation N_24		Left Saccade N_25	
Time	6089	Time	6408
Duration	319	Duration	110
X	569	Start point	569,254
Y	254	End point	1258,235
		Blinks	0

Fig. 12. Popup tips over a) fixation, b) saccades

All tips contain the name of the object. The name consists of the eye-side (left on example), event name (fixation or saccade) and ordinal number (like N_{24}). Tips over fixations have its time, duration and coordinated values. Tips over saccades have its time, duration, start and end points coordinates, and the number of blinks occurred during a saccade.

Visualization options. iComponent has very powerful view customization abilities. Users can change properties of objects in a view with a high flexibility. The *Visualization options* dialog contains all relevant controls to archive the best visualization. This dialog consists of several pages and contains controls to adjust all options of all visualizations, but only pages related to the currently presenting visualization are available.

For instance, the page “Fixations” allows defining fixation data mapping mode to circle, its colors and default properties’ values (Fig. 13).

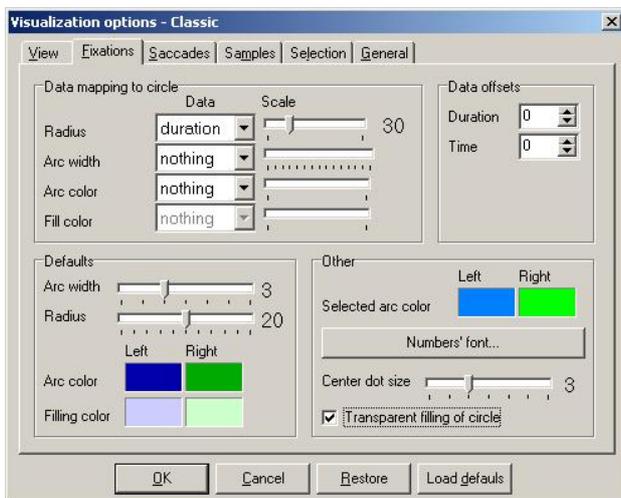


Fig. 13. Options of the visualization *Classic*: page *Fixations*

Since data mapping can be applied to all circle features at the same time, the fixation visualization can appear quite complex. For example, fixation duration can be represented by circle radius, filling color and arc width at the same time (Fig. 14).

All colors in the options dialog are doubled: the colors below the label *Left* will be applied to the fixations and saccades produced by the left eye, and the colors below the label *Right* will be applied to the fixations and saccades produced by the right eye. This separation by colors would take place only if the recording loaded

contains both left and right eye movement data, otherwise the colors from left column are supposed to be used only.

The page “General” is accessible from any iComponent view and contains settings applicable to all views (Fig. 15). The option *Eye* is available only if the recording loaded contains data of both eyes. Users may choose between left and right eye data to use in visualization.

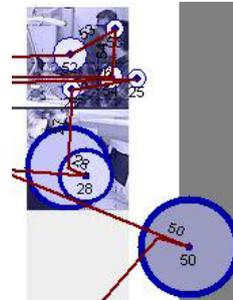


Fig. 14. Fixation appears as circle, where filling color, radius and arc width depend on fixation duration.

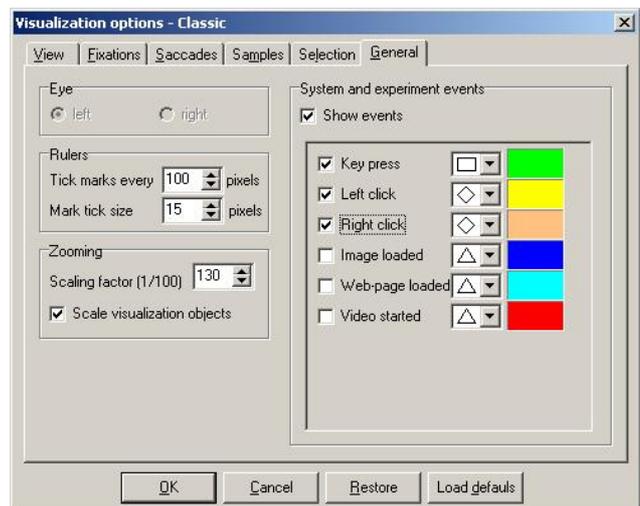


Fig. 15. Options of the visualization *Classic*: page *General*

Conclusions

This paper describes iComponent, a tool for visualization and analysis of eye gaze data. It facilitates basic research on eye movements as well as using eye gaze for computer input.

The tool developed implements all main types of gaze data visualization methods. Each kind of visualization has a set of features available only in iComponent. These include:

- system and experimental events visualization;
- highly adjustable visualization objects: colors, sizes, fonts;
- convenient view zooming and panning;
- data mapping concept (fixations, saccades and samples) for representing the object’s properties;
- manual drift correction by drag-and-drop actions;

- various combinations of fixations/saccades and samples visibility;
- hints over objects or events with short information;
- navigation among fixations and samples.

Experiments on eye movements conducted using iComponent as a tool verified its usefulness (see, e.g., [4, 5] for details).

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Presented for publication 2006 02 21

O. Špakov, D. Miniotas. Highly Flexible Software for Gaze Path Analysis and Visualization // Electronics and Electrical Engineering. – Kaunas: Technologija, 2006. – No. 7(71). – P. 23–28.

The growing interest in using eye-movements for human-computer interaction has also increased the need for tools to investigate and analyze the behavior of human eyes. Nowadays, there are many commercial and academic products available for researchers in this field and the quality and accuracy of eye-tracking devices are constantly increasing. Despite the numerous methods developed for analyzing and visualizing gaze paths, however, no universal tools are available yet to accomplish this. To fill in this gap, we developed iComponent – a software product with a highly flexible architecture for easy development of interchangeable plug-in modules to support various eye-tracking devices and experimental software. iComponent has four types of 2D visualizations of gaze data and one type of 1D visualization. The 2D visualizations are superimposed on the stimulus seen by the user during a session. Three of the visualizations are capable of showing several subjects' gaze paths simultaneously. Ill. 15, bibl. 5 (in English; summaries in English, Russian and Lithuanian).

O. Шпаков, Д. Минютас. Гибкое программное обеспечение для анализа и визуализации траекторий взгляда // Электроника и электротехника. – Каунас: Технология, 2006. – No. 7(71).– С. 23–28.

Растущий интерес к использованию движений глаз во взаимодействии между человеком и машиной одновременно повышает спрос на средства для изучения таких движений и взаимодействия. Работающим в этой области ученым в настоящее время предлагается широкий выбор как коммерческих, так и некоммерческих систем, а качество и точность таких систем постоянно растет. Однако несмотря на разнообразие всех методик для анализа и визуализации траекторий движения глаз, пока что не создано универсальных средств для этой цели. В настоящей работе описывается программное обеспечение „iComponent“, которое предназначено для заполнения упомянутой брешы. Гибкая архитектура этого программного обеспечения очень облегчает создание вложенных модулей обмена данными, таким образом позволяя использовать разные приборы регистрации движения глаз и программное обеспечение для проведения экспериментов. В системе „iComponent“ кроме одномерной визуализации траектории взгляда существует четыре способа представления данных в двумерном пространстве. Последние визуализации производятся поверх графических изображений использованных во время эксперимента. Ил. 15, библи. 5 (на английском языке; резюме на английском, русском и литовском яз.).

O. Špakov, D. Miniotas. Lanksti programinė įranga žvilgsnio trajektorijai analizuoti ir vizualizuoti // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – No. 7(71).– P. 23–28.

Didėjant susidomėjimui akių judesių panaudojimu žmogaus ir kompiuterio sąveikai, taip pat didėja ir priemonių, skirtų žmogaus akių judesiams tirti, paklausa. Šioje srityje dirbantiems mokslininkams dabar siūlomas platus komercinių ir nekomercinių sistemų pasirinkimas, o šių sistemų kokybė ir tikslumas nuolatosis gerėja. Tačiau nepaisant visos žvilgsnio trajektorijai analizuoti ir vizualizuoti skirtų metodikų įvairovės, kol kas dar nėra sukurta universalių šiam tikslui skirtų priemonių. Šiame darbe aprašoma programinė įranga „iComponent“ buvo sukurta tai spragai užpildyti. Lanksti programinės įrangos architektūra labai palengvina kurti pakeičiamus įdedamuosius modulius ir tai leidžia naudoti įvairius akių judesių registravimo įtaisus ir eksperimentavimui skirtą programinę įrangą. Naudojant sistemą „iComponent“, be vienmatės žvilgsnio trajektorijos vizualizacijos, galima gauti keturis duomenų atvaizdavimo dvimatėje erdvėje būdus. Taikant šiuos būdus, žvilgsnio trajektorija atvaizduojama kartu su eksperimento metu naudotais grafinais vaizdais. Il. 15, bibl. 5 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).