# Visualization of User Eye Movements for Search Result Pages

Yuka Egusa
National Institute for Educational Policy Research
3-2-2 Kasumigaseki,
Chiyoda-ku, Tokyo 100-8951, Japan
yuka@nier.go.jp

Masao Takaku
National Institute for Materials Science
1-2-1 Sengen,
Tsukuba, Ibaraki 305-0047, Japan
TAKAKU.Masao@nims.go.jp

Hitoshi Terai
Tokyo Denki University
2-1200 Muzai Gakuendai
Inzai-shi, Chiba 207-1382, Japan
terai@sie.dendai.ac.jp

Hitomi Saito
Aichi University of Education
1 Hirosawa, Igaya-cho
Kariya-shi, Aichi 448-8542, Japan
hsaito@auecc.aichi-edu.ac.jp

Noriko Kando
National Institute of Informatics
2-1-2 Hitotsubashi
Chiyoda-ku, Tokyo 101-8430, Japan
kando@nii.ac.jp

Makiko Miwa
National Institute of Multimedia Education
2-12 Aoba
Mihama-ku, Chiba 261-0014, Japan
miwamaki@nime.ac.jp

## Abstract

*We propose new visualization techniques for the user behaviors when using search engine results pages. Our visualization method provides an overview of a user's actual visual behavior using the logs for eye-movement data and browser link-clicking. We also report on the eye-movement data collected from user experiments.*

**Keywords:** *visualization, eye-movement analysis, Web search*

## 1 Introduction

Evaluation of the search effectiveness of Information Retrieval (IR) systems is extremely important in today's Internet environment, where a wide variety of IR systems are available for use.

We focus not only on the ranking of retrieved documents, but also on the user's actions with respect to the search result pages. A user's actions are important because they reflect the user's cognitive process and these actions have significant value for the user-centered evaluation of IR systems.

We describe new visualization techniques for the user behavior using search engine results pages. Our visualization method provides an overview of a user's actual visual behavior using the logs for eye-movement data and browser link-clicking. We also report on the eye-movement data collected via user experiments.

## 2 Related Work

There have been several IR studies [1][3][4][5][6][7][8][9] where eye-trackers were used. However, as pointed out by Lorigo et al. [7], more research is needed in this area because there are many challenges on the way towards developing methods of analyzing eye-tracking data and integrating these data with other usability methods.

For ranking purposes, Lorigo et al. [8] analyzed a user's viewpoints and their transitions on a search engine's results page by using a scanpath methodology. Their scanpath method takes a user's viewpoints at a particular rank and the transition between ranks, and then constructs a series of ranking sequences as a scanpath. For example, if a user viewed the document abstracts in a results page that were ranked two, one, two, two, and three(Fig. 1), in that order, the scanpath could be expressed as "2-1-2-2-3". Lorigo et al. [7] proposed a visualization method for these scanpaths. Their visualization method uses a circular representation, where the viewpoints in a ranking are placed counterclockwise in the circle (Fig. 2).

Although our visualization method is similar to that of Lorigo et al., our method depicts the scanpath horizontally and combines click-through data in the visualization. In addition, the visualization shows the

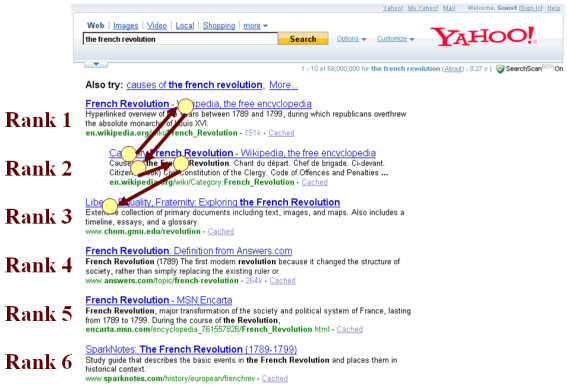


**Figure 1. Example of scanpath on screen**

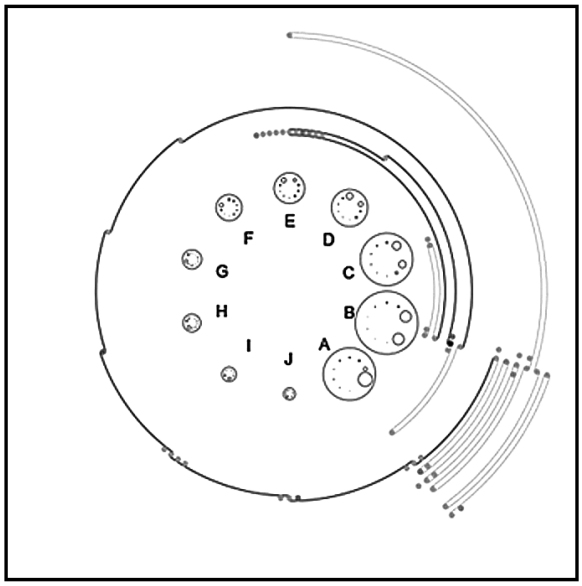


**Figure 2. Lorigo et al.'s visualization [7, p. 1049 (Fig. 4)]**

overall pattern of the scanpaths during an exploratory search.

## 3 Data for visualization

We used data from a real experiment for our visualization. Eleven undergraduate students and five graduate students ranging in age from 19 and 28 years old participated in our experiment. Nine were male and seven were female. The undergraduate students' academic majors included economics, literature, electronics engineering, Spanish language, psychology, chemistry, and civil engineering, and the graduate students' were library and information science. The participants were required to conduct two different types of Web searches[2]: a report-writing task where they were required to collect information from multiple Web pages concerning a topic on world history, which is a requisite subject for all high school students in Japan. The other was a trip planning task where they were required to collect information to plan a trip for their friends and families. We wanted to capture the participants' natural exploratory searches. Therefore, we instructed them to select a particular topic of their own interest for both tasks. We instructed them to use their favorite search engines and to bookmark useful Web pages. The participants had 15 minutes to do each task. We recorded the logs of their browsing histories, captured the images from their screens, their eye movements, and their think-aloud protocols.

We categorized their recorded eye positions during searching the search results pages into specific look-zones. We manually added annotations to their eye movements based on their eye movement data and browsing histories. Please refer to Terai et al.[10] for more details on the experiment and the data analysis, where an analysis of 11 undergraduate students' data was reported.

## 4 Visualization Method

Figure 3 shows our visualization of the scanpaths for a participant during a 15-minute search session. Before constructing the visualization, we converted the analyzed eye-movement data, the link-clicking data, and the queries into a scanpath as follows:
"`2-2-3-3-3-3-4-3-link->(4) The French revolution`"
This represents a scanpath for the query *the French revolution*, with the user viewing the sequence of document abstracts ranked two, two, three, three, three, three, four, three, and then clicking the fourth-ranked link. The original scanpath expression for Fig. 3 is shown in Figure 4.

The "Rank 1" rectangle at the top of Fig. 3 represents the area for the document abstracts ranked first among the search results pages, and "Rank 2" represents the area for the second ranked, and so on. The bar chart above each rank rectangle shows the fixation rate for the rank, which is the proportion of the rank's fixations within the total fixations recorded during the task. For example, in the case of Rank 1, the participant viewed the first-ranked area for 31.1% of the total fixations for the task. The filled-in bars indicate the link-clicking during the task for the corresponding ranks. Each circle below the rank rectangles indicates one fixation in that ranked area (i.e., the number of circles shows the number of fixations). The unfilled circles represent the first fixation for a query. For example, the first fixation for the query "wikipedia" was an area of Rank 2, and the first for the query "The French Revolution" was an area of Rank 1.

We connect the circles using lines following the order of the viewing results per query. A solid line con-

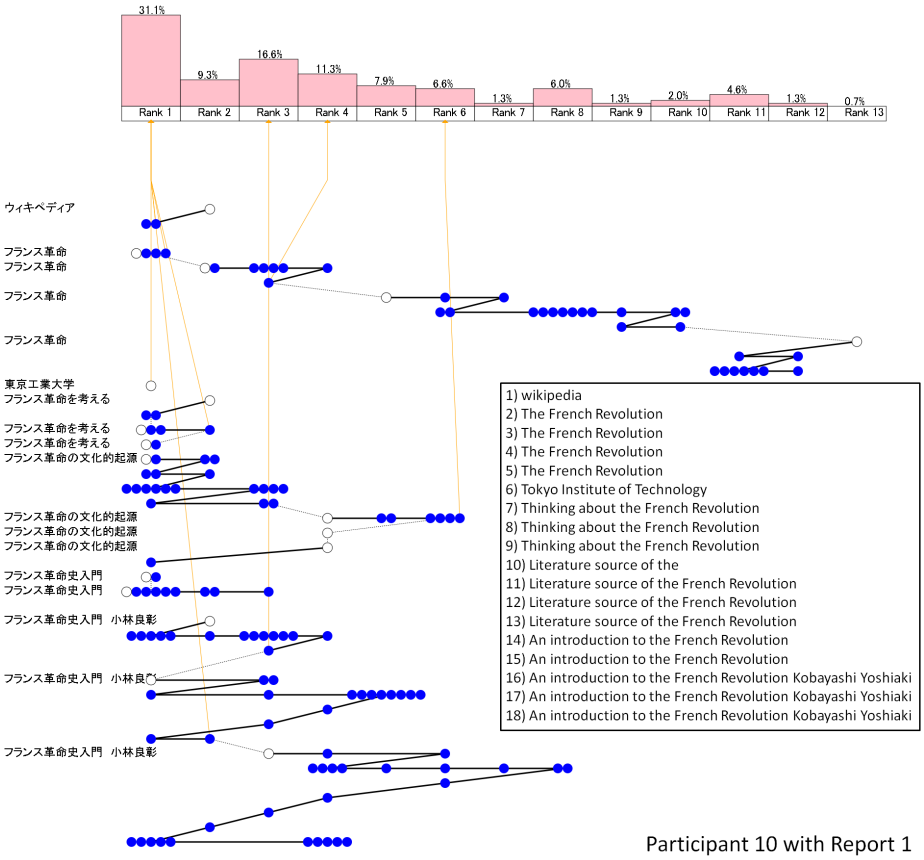


**Figure 3. Example of scanpath visualization for a participant in the Report task**

nects the fixations on the same search results page. A dotted line means that the participant returned to the results page after leaving it for a while, i.e., the participant clicked a link that went back to the results page.

As shown in Fig. 4, the participant made seven queries from "wikipedia" to "introduction to French Revolution Kobayashi Yoshiaki". These queries are shown on the left in the figure (In rectangle on the right, we translated the original queries into English from Japanese). For the "wikipedia" query the participant viewed Rank 2 first, then Rank 1, and finished the query. An arrow from a fixation circle means that the participant clicked a link having the rank of the arrow's destination after fixation. For example, in the query "Tokyo Institute of Technology", the participant viewed Rank 1 first and then clicked the link of a document having Rank 1.

In this task, the participant frequently viewed Rank 1 through Rank 3 areas, with a single query being viewed under Rank 9. This type of scanpath visualization helps us grasp the participant's information-seeking process and the relationships between the clicked links and rankings.

The scanpaths of the Report and Trip tasks by four participants are shown in Fig. 5. These side-by-side visualizations are drawn on the same scale. So, we can easily compare the patterns among the tasks and participants. The first two scanpaths are extremely short, the next two are of middle length. Fig. 5-a shows that the user submitted only one query in his task and clicked Rank 1 shortly after looking at the abstract listed on the results page. Fig. 5-b shows that the user submitted two queries. In the first query he/she looked at a Rank 2 abstract three times, then Rank 1, and in the second query he/she looked only at the Rank 1 abstract. He/she did not click any links on the results page for both queries. Fig. 5-c shows that the user submitted nine unique queries, and at most looked up to Rank 20 abstracts, and clicked a few links on almost every search results pages. Fig. 5-d shows similar pat-

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2-1-1-link->(1) wikipedia
1-1-1-1-link->(1) The French Revolution
2-2-3-3-3-3-4-3-link->(4) The French Revolution
5-6-7-6-6-8-8-8-8-8-8-8-9-10-10-9-10 The French Revolution
13-11-12-11-11-11-11-11-11-12 The French Revolution
1-link->(1) Tokyo Institute of Technology
2-1-1 Thinking about the French Revolution
1-1-1-2-link->(1) Thinking about the French Revolution
1-1 Thinking about the French Revolution
1-1-2-2-1-1-2-1-1-1-1-1-1-3-3-3-3-1-3-3-link Literature source of the French Revolution
4-5-5-6-6-6-6-link->(6) Literature source of the French Revolution
4 Literature source of the French Revolution
4-1 Literature source of the French Revolution
1-1 An introduction to the French Revolution
1-1-1-1-1-1-2-2-3 An introduction to the French Revolution
2-1-1-1-1-1-2-3-3-3-3-3-3-4-3-link->(3) An introduction to the French Revolution Kobayashi Yoshiaki
1-3-3-1-3-5-5-5-5-5-5-5-4-3-1-2-link->(1) An introduction to the French Revolution Kobayashi Yoshiaki
3-4-6-4-4-4-4-5-6-7-8-8-6-4-3-2-1-1-1-1-1-4-4-4-4-4 An introduction to the French Revolution Kobayashi Yoshiaki
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**Figure 4. Input data for the scanpath visualization**

terns to Fig. 5-c.

## 5 Conclusion

We have proposed new visualization techniques for a user's scanpath based on a visualization method suggested by Lorigo et al. [8]. Our method is different from their work in the following six respects:

- Multiple scanpaths for the whole task are displayed in one diagram.
- Scanpaths for the same query are connected using a dotted line.
- Queries are displayed.
- Scanpaths are depicted horizontally.
- Users' link-clicking data are combined with their scanpaths.
- Fixation rates for each rank are described via a bar chart.

This method shows the number of query searches for a task in the vertical dimension, and the time taken to deeply examine the search results in the horizontal dimension. Furthermore, we expect that it will enable us to reveal the differences in information-seeking processes between tasks and between users. By presenting the visualizations of multiple tasks side-by-side (Fig. 5), we can compare the user behaviors of these tasks by different users: e.g. how further in the rankings the users are looking at abstracts, how many they are browsing. This will help us to identify the interesting patterns of a user's behavior for it.

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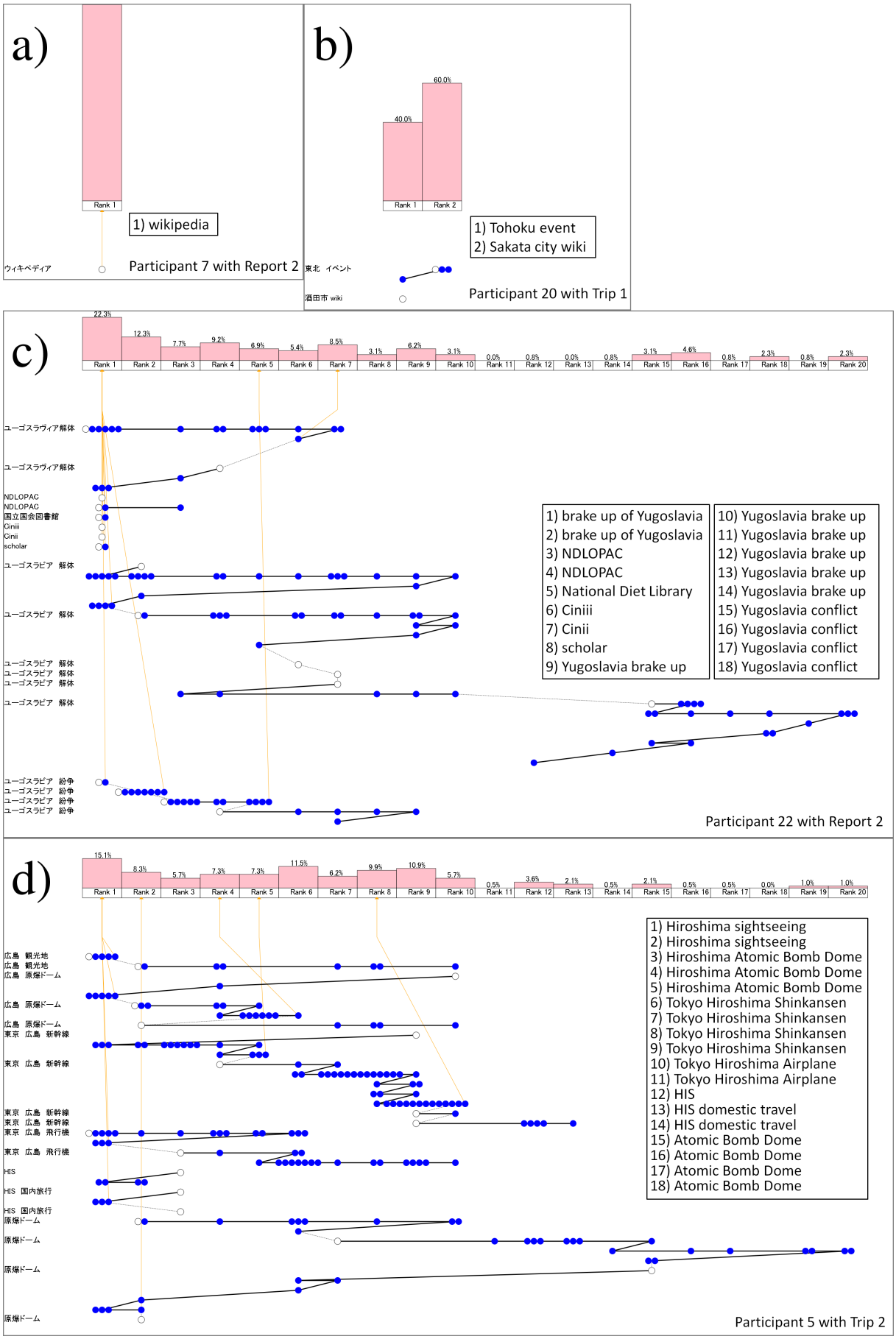


**Figure 5. Example of scanpath visualization for multiple tasks**