A Circular Visualization of People’s Activities in Distributed Teams

Paolo Buono, Maria Francesca Costabile, Rosa Lanzilotti
Dipartimento di Informatica, Università degli Studi di Bari Aldo Moro
Via Orabona, 4 - 70125 Bari
{paolo.buono, maria.costabile, rosa.lanzilotti}@uniba.it

Abstract—When working in distributed teams, it is very important to be aware of the activities of all members, since it provides hints about when they might be available for collaboration. We propose a novel visualization technique that combines several representations to show the daily patterns of team members’ activities. It uses a 24 hours circular display to facilitate international collaboration across time zones. Current calendar information can be compared to the typical patterns and reveal likely availability. User studies evaluating the tool that implements the proposed technique are reported and discussed.

Keywords—Circular BoxPlot, Circular Histograms, Activity Traces.

I. INTRODUCTION

The use of technology to allow people collaboration dates back to the sixties [1]. Today the growth of social networks and the increasing number of projects, whose development teams are distributed world-wide, have generated increasing attention to systems and tools that support remote collaboration, in order to replicate co-located collaboration conditions. However, coordination and collaboration among members in distributed teams is affected by several distance factors, which influence effectiveness and/or efficiency of the collaboration. Pallot et al. analyze 25 different distance factors and group them into four dimensions: structural, social, technical and legal. Lack of interpersonal awareness is identified as a social distance that influences collaboration effectiveness: each collaborator needs to know what the others are doing and the problems they are facing, in order to be able to organize his/her own contribution to better fit with others’ activities [2].

Lack of interpersonal awareness is seen as one of the most problematic factors in software development activities [3]. Distributed team collaboration is mediated by software systems that collect data to keep track of team members’ activities in exchanging messages, scheduling meetings, sharing and modifying documents, etc. Such data are called activity traces; they can provide hints for identifying when a person might be available for communication.

This paper describes a novel technique that visualizes activity traces of people collaborating in distributed teams. In the example presented, activity traces refer to sent emails, chat messages, keyboard/mouse use and workstation login/logout. Other activity traces could be considered, depending on the context of use. Even if this technique also uses some visual representations already known, it combines them in an original visualization based on a clock metaphor, in which 24 hours are displayed in order to facilitate international collaboration across time zones. The aim is to foster interpersonal awareness by providing clues about collaborators availability through an overview of the daily activities performed by individuals in a globally distributed team. With respect to previous proposals about visualizing activity traces (e.g. see [5], [7]), a further novel contribution of our technique is that it visualizes activities of several individuals at once, quickly conveying information about their location, their availability at the current time and in the next 24 hours. The visualization thus permits understanding of time relationships among team members and the identification of patterns occurring during daily activities.

Initial ideas about this visualization technique were presented through a poster at a recent conference [4], without any focus on the motivation and on all the features of the current visualization tool. In particular, a feature not already available in the prototype described in [4] is the visualization of the team members’ planned schedule in the represented 24 hours. This information is useful since it provides further clues about collaborators’ availability.

This paper discusses the rationale and illustrates all the novel features of the proposed visualization technique, also reporting the performed evaluation studies. It has the following organization. Related works are reported in Section II. The metaphor and the visual representations adopted by the technique and an example of its usage are described in Section III. The user-centred design and the evaluation studies carried out with the involvement of users and domain experts, are reported in Section IV. Finally, Section V concludes the paper.

II. RELATED WORK

The literature reports several proposals of visualizing activities of collaborative teams. We distinguish two categories of papers: those that focus on visualizing the structure of teams and those that focus on activities of a single member. Papers in the first category highlight temporal and social structures of the communications among members, while the others visualize activity traces, in order to help a member in planning his/her own activities and communication.

An example of visualization in the first category is provided by Fisher and Dourish, who represent the structure of a team through a graph, whose nodes are the members and links are
the emails exchanged among them [5]. The visualization allows users to make assumptions about the roles of the members of the team (social structure). The paper also proposes a tabular visualization, which shows the top 10 collaborators, ordered according to the number of messages that a specific member sent to the others, grouping the data by week or by month. This provides hints about the interaction frequency between the user and the team members shown in the list.

Another example of visualizing distributed teams through graphs is provided in [6]. Specifically, authors visualize directed graphs in which nodes represent users locations, indicated on a geographic map, and links represent different relationships, like contributions to the same project. They also show small multiple displays combining multiple views in order to enable visual comparisons, and matrix diagrams that should reveal specific relationships. Such visualization helps understanding the social structure of the team, but does not provide any indication about members’ availability for collaboration in the near future.

![Line chart representing activities of two persons in different time zones.](image)

In the second category, Begole et al. visualize activity of a single member and try to analyze some activity temporal patterns, also called rhythms [7]. They present a number of visualizations of the data that exhibit meaningful patterns in users activities. Examples of monitored activities are: computer activity, appointment span, home activity, and office activity. A line chart is used to show the average of the data about an individual’s activities over a time period. It is easy to show that a linear representation is not very effective, since it fails to give the continuity of the activities along the time, especially when considering different time zones. An example, created with MS Excel, is shown in Fig. 1: the line chart represents activities of two persons (one in blue and one in red) that, starting at 7 in the morning, work 8 hours each and live in time zones that differ 11 hours. The activities of the person (red line) who works from 21 (9 PM) till 4 AM the next day is divided in two parts, which makes more difficult its interpretation. The visualization technique we propose uses a clock metaphor, which works well in visualizing daily activities of team members working at different time zones. The shape of the visualized “clock” is the one of an analogical 24 hours clock, in order to represent the whole day.

![Line chart representing activities of two persons in different time zones.](image)

In literature, there are a few articles that somehow compare linear versus circular representations (e.g. [1], [18]). They remark that the choice between linear and circular depends very much on the user’s task, which is the reason we choose the circular representation. Indeed, Kessel highlights that, even if in most cases people tend to use linear representations, they actually prefer circular representation for cyclic events, e.g. natural processes, seasons and, in particular, human activities along the 24 hours of the day [1].

The clock metaphor was used in visualizations proposed for other application domains. An example is spiralClock [8], which shows events planned for a conference and displays the time along a spiral. This would not work in our case, since, in order to show activities of more people, the visualization of multiple staked spirals becomes soon crowded.

MarkerClock is a clock-based visualization proposed in a context of caring for older adults, which uses circular stripes [9]. It shows only 12 hours, but the very limitation is that only one data type can be visualized, while our visualization display traces of multiple types of activity.

Our technique uses circular visualization in order to make the continuity and periodicity of time intuitive. A survey on circular methods for information visualization is provided in [10]. However, among the many circular visualizations proposed so far in different domains and for different goals, very few are oriented to the visualization of daily activities that explicitly visualize the time of the day. In particular, Zhao et al. propose pieTime, a pie visualization that shows activities like email and phone calls, visualized on different time scales, in order to reveal temporal activities in user behavior [11].

With the purpose of exchanging information about people’s availability and increasing their interpersonal awareness, shared online calendars, such as Google calendar, could be used, since they permit management and coordination of events with other people. However, it has been shown that they fail in this purpose, because often people’s calendars are just time-planning and the planned schedule might substantially differ from what actually happens. Lovett et al. remarked that calendars do not represent reality well, since genuine events are hidden by a multitude of reminders and placeholders [12]. In their research, they found that most calendar events (49%) were used as personal reminders (e.g. a reminder to backup files), and another relevant quantity of events (32%) were used as placeholders, (e.g. recurring daily meetings), with no evidence that certain events actually occurred. They also suggested that the reliability of calendar representation of events can be improved by taking into account other types of data, e.g. data about event locations or data coming from other sources, like data from social networks. Other authors employ predictive user models of event attendance and text mining of event descriptions to improve the reliability of shared events [13]. For the purpose of the visualization, we are mainly considering how to represent this information in order to provide clues about collaborators’ availability.

In order to contact a person, it is useful to know his/her current status, which is common in today’s most well-known computer mediated communication systems. For example, Skype indicates four alternatives: Online, Busy, Away, Offline. This indication is unreliable since people often forget to change their status. Various solutions try to overcome this drawback. The one proposed by MyVine is to model availability for communication by using laptop microphones to sense nearby speech, combined with location sensor data, computer and
calendar information [15]. Our tool displays both status and activities, as described in the next section.

III. THE CLOCKBOXPLOT (CBP) TECHNIQUE

The goal of the visualization technique described in this paper is to provide an overview of typical activities performed by members in a team, in order to give information about their availability. To this aim, two principal types of information are visualized: a) daily activity traces; b) planned activities in the next 24 hours according to shared calendars.

The technique uses a basic visual representation called circular stripe (or simply stripe). As shown in Fig. 2, it is inspired by the mathematical concept of annulus, i.e. it is the area between two concentric circumferences. It is also called doughnut or ring. A stripe is the area in which activity traces related to an individual are displayed, as described below.

The technique is called ClockBoxPlot (CBP in the rest of the paper), since it exploits a clock metaphor and represents, in a compact way, activity traces through the boxplot representation.

John Tukey introduced the boxplot, also called box and whiskers plot, as part of his toolkit for Exploratory Data Analysis [16]. A boxplot provides a summary of the distribution of data, ordered by their frequency. The main component is the box, whose size represents data between the lower and upper quantile, called lower hinge and upper hinge respectively (see Fig. 3). Two whiskers connect hinges to extremes that are out of the box: they represent the values with the lowest and the highest frequencies, respectively (lower extreme and upper extreme). The length of the lower whisker represents the distance between the value with the lowest frequency and the lowest quantile. The median of the data is indicated in the box. In addition, potential outliers are represented outside the boxplot (not shown in Fig. 3).

Boxplots provide compact representations of data by displaying less details than histograms, but taking less space. They are useful for comparing distributions across different groups of data. The boxplot used in CBP does not show the median and the outliers. Moreover, because it is visualized within a stripe, a circular boxplot is used, as shown in Fig. 4.

Histograms have been added to CBP in order to visualize, in more details with respect to boxplot, data referring to a specific activity of a person. The histograms are drawn inside the stripe, thus they are visualized as circular histograms, whose bins are displayed along a circumference. Since a stripe is delimited by two concentric circumferences, each stripe can contain two histograms, one with bars placed outside the inner circle and one with bars placed inside the outer circle. Fig. 5 shows the two histograms drawn in a stripe.

Fig. 6 is a screenshot of the ClockBoxPlot tool that implements the CBP visualization technique. The external circle has 24 hours indicated on it. In this example, six stripes are visualized. The innermost circle shows the current time (16:24) and user location (Bari), also indicating the time zone expressed with reference to the Greenwich Meridian Time (GMT +1). Each stripe refers to a team member and, by using two histograms (one in purple and one in blue) and one boxplot (in yellow), it represents activities of that member in the 24 hours after the current time (16:24). The boxplot represents different data about a person’s activities on a computer, such as keyboard stroke frequency and login/logout timestamps. It thus indicates the time intervals in which a person is typically active on his/her computer. By taking into account the structure of the boxplot, in the time intervals corresponding to whiskers, the probability to find the person available is lower.
In the example in Fig. 6, the blue histogram shows frequencies of chat messages that the specific member has sent to other team members, while the purple histogram shows frequencies of email messages. Other activity traces could be available; in this example, they are system login/logout and key press frequencies. The CBP tool allows the user to select those activities that he/she wants to visualize in more details, which will be shown by the two histograms. The remaining activity traces are visualized with the boxplot, which thus represents the probability that the collaborator will be available for communication on the basis of the other collaboration traces. This probability is computed by using algorithms like those in [7].

Since the objective of the visualization is to give information about people’s availability, it is useful to add data coming from shared calendars, in order to indicate time intervals in which a person would likely be busy. For privacy reasons, it is more likely that a person can make available calendar events without specifying the nature of such events but only their time intervals. Such intervals in which the person will be busy are grayed in the stripe.

Even if the time at the user location is indicated at the center, the CBP also uses a black hand pointing at the user’s time on the clock, in order to make easier to analyze the activities visualized in the different stripes starting from that time. The activities are actually visualized from the time indicated in the center (i.e. starting from the black hand) up to the next 24 hours.

The example in Fig. 6 shows six stripes, each one corresponding to one member listed in the panel on the left of the screen, where other information is provided. Specifically, one of them lives in Bari, one in New Delhi, one in Moscow, one in Rome, one in Beijing, one in New York. It is also indicated the time zone with reference to GMT. The order of the names in the list corresponds to the stripes going from the outmost to the inmost stripe. Thus, the outmost stripe represents the activities of “Alessandro Di Bari”. The yellow boxplot spans from 9:55 to 15:25; one whisker is set at time 9:35 and the other one at time 15:50. This means that the probability that this specific member will be available is higher between 9:55 and 15:25, it is lower between 9:35 and 9:55 and between 15:25 and 15:50, and almost zero in the remaining time. Furthermore, “Alessandro Di Bari” has some events scheduled between 8:40 and 10:00 and between 14:30 and 16:24 of the next day. Actually, we cannot know if he will be available after 16:24, because the shown time interval is 24 hours. In the shown example, it is evident that the four most outside members can easily find time to work together, but for Lan and Brown (the two inmost stripes) it is harder to meet.

Often a user needs to compare the activities of two collaborators. This is much easier if the corresponding stripes are visualized one next to the other. The user can change the
stripe order by a simple drag and drop. Several users that tried CBP found this feature very useful, not only for comparison purposes, but also to better observe activities of a member, because more external stripes are bigger than more internal ones. In addition, a stripe can be zoomed by clicking the lens icon of the corresponding member in the users panel. For example, Fig. 7 shows the same CBP of Fig. 6 with the outermost stripe zoomed.

Looking at Fig. 6, one may wonder about scalability issues. Our experience shows that even if many people participate in teams, the actual collaboration is often limited to a small number of them, not greater than a dozen. When the list of members does not fit in a screen, a scrollbar appears at the left side of the users panel. Moreover, the user not interested in analyzing certain members can temporarily remove them from the visualization by clicking on the X icon in the member panel (see Fig. 6). The user can come back to the complete member list by clicking on the ‘reset’ icon on top of the member list.

Figure 7. Outermost stripe zoomed in order to better observe it. A click on the stripe or on a member in the list highlights both the member and the associated stripe.

IV. USER-CENTRED DESIGN OF CBP

The tool has been developed by following a User-Centred Design approach: different prototypes have been created and analyzed in formative evaluation sessions, whose results were instrumental to improve the quality of the successive prototypes. Different qualitative studies, involving users and experts in HCI and application domain, were performed, as summarized in this section.

A. Informal usability evaluation

The first CBP prototypes were analyzed through informal usability evaluations. Specifically, 5 Computer Science PhD students (3 males), who had attended an InfoVis course, analyzed independently the first paper prototype. Their comments were discussed with HCI experts and taken into account for implementing an early version of the CBP tool. Two successive running prototypes were analyzed in two different sessions: the first involved two researchers working on data analysis, while three experts of collaborative software development evaluated the second prototype. Each participant was individually asked to explore the CBP prototype. An HCI expert observed the interaction, acting as a facilitator whenever some difficulties arose and taking notes of the interface aspects that appeared more problematic. The results suggested to perform changes in order to provide appropriate feedback to the user, addressing, e.g., use of colors, legend terms and layout, status visualization and stripe visualization.

B. User test

A user test was performed on the running version of the CBP described in this paper. It was an observational study aimed at receiving user feedback on its design and usability.

A total of 6 senior students (4 male), aged 21-23 years old, participated in the study as their assignment for the InfoVis module in the HCI course. The current use of CBP is for distributed software design teams, thus these students represented a proper users sample, since they have experience in software design and development and use version control systems. An HCI researcher acted as a facilitator during each individual test session in a university laboratory. Another HCI researcher took notes. Each session consisted of three phases:

1) Understanding. 5 minutes were given to the participants to observe and provide their interpretation of the visualization. They did not interact with the tool but only commented on the different visualization elements, explaining what they understood about their meaning and their possible functionality. The facilitator intervened to prompt the participant to provide his/her interpretation.

2) Get familiar. Participants were asked to use the tool, performing 6 simple tasks, in order to get familiar with the interactions they could perform with the various visualization elements. Specifically, the first task asked to select, among the available teams, the “iOS developer.json” team. The second task required to zoom on a stripe associated to a member. Third and fourth tasks required to switch the position of two different pair of stripes. The fifth task asked to remove from the visualization a member and the associated stripe. The last task required to reset the visualization to the initial state.

3) Execution. Participants were asked to perform 6 typical tasks a user would carry out with CBP. These tasks were presented as questions, whose answers required an interpretation of some of the visualized data. However, the interpretation is facilitated if the user properly manipulates the visualization. The questions were about identifying availability of team members at specific times, which is the main purpose of CBP. For example a question was: “It’s 7 PM. Could Roger Brown receive an immediate reply from John Smith in case he...
The tasks performed by the participants in the \textit{Execution} phase required more time than those in the \textit{Get familiar} phase, also because they did not list the sequence of actions to perform, but they were formulated as questions to whom an answer should be provided. The user who had difficulties in the previous phase was not able to complete successfully the 6 tasks. Again, he showed problems in associating members and stripes; in some tasks, even if he correctly manipulated the visualization, he provided wrong answers about times. The remaining five participants successfully completed 28 out of 30 tasks. The failure of two participants for a same task was partial, since the sequence in the performed actions was correct but the final answer was wrong because the two participants misinterpreted the time in different time zones. The average time to complete all 30 tasks (of all five participants) was 3 minutes.

The observation of the participants during the \textit{Execution} phase revealed that two different strategies were used to compare two stripes. Specifically, some participants zoomed the more internal stripe in order to enlarge the circular histograms and the boxplot, improving their readability. In this way it would be easier to compare with the other more external stripe, in which histograms and boxplot are bigger. The other strategy consisted in putting two stripes close each other by modifying the order of the members in the member list.

Participants immediately got familiar with the clock metaphor. All of them well understood that the visualization represented activities of the whole day. Only two of them did not immediately realize that the visualized period started at the moment of the use of the tool and ended the day after at the same time. Once this was explained to them, they did not have further difficulties.

C. Focus group with domain experts

Besides usability of the tool, we were very much interested to get more information about the utility of CBP for expert users and about possible uses in other contexts. Thus, we recently carried out a focus group that involved four experts of distributed software development, who are colleagues at our University. They were different from the three colleagues that analyzed one of the first prototypes, as reported in Section IV.A. Before the focus group, a session was planned to let each participant interact with CBP in a quite research laboratory. This session had the following organization. Initially, the participants watched a video of about two minutes that gives a demonstration of the CBP functionality. Then, the participants had a few minutes to practice with the tool. This practice was stopped once the participant said that he/she got familiar with the tool and understood the tool functionality. During this session, an HCI researcher acted as facilitator. He was answering possible questions but also prompted the participant to perform tasks similar to those performed in the \textit{Execution} phase of the user test. Another HCI researcher took notes about the participants’ interaction. Again, we were not interested in quantitative measures about the executed tasks, since such measures have a value only when considering much larger user samples. We wanted that the participants could understand the possibilities offered by the tool, in order to later discuss in the focus group about its utility in their work.

After each participant individually practiced with the tool, the focus group was held in a meeting room at our laboratory, with the two HCI researchers acting as moderator and observer, respectively. The discussion started by asking their impressions on CBP (Was it difficult to understand? Easy to use? etc.), but soon focused on their opinion about the utility of CBP, the existence of similar tools, its possible integration in collaboration tools they currently use. Then, participants were asked to discuss possible uses in different contexts in which people collaboration is important. Participants’ interaction with the tool was video-recorded, while the focus group was audio-recorded. Later, video and audio were transcribed for the analysis.

All participants didn’t know any similar tool, and they agreed on the utility of CBP as an effective tool for presence awareness. They appreciated very much the visualization at a
glance of the activities of team members that CBP provides. One participant mentioned the possible use of CBP in collaborative development environments, such as Microsoft Team Foundation Server or IBM Rational Team Concert. The other participants agreed. About other possible uses, CBP was judged useful for working contexts but not, for example, in social networks, which are mainly used for contacting friends and for entertainment. A participant explained that it is really difficult to know the schedule of a friend, so it is easier to setup a doodle when planning a meeting with friends.

A participant remarked that CBP could be useful also in code versioning systems, in which a team of developers is involved. It is very important to know data related to specific actions of each developer, e.g., visualizing data about commits, pull and pushes, ticket requests, branches and forks, etc. For example, agile development is characterized by frequent commits. Another participant proposed himself to be part of a longitudinal study, in which the tool could be integrated as a plugin in Firefox. He was interested in visualizing primarily email messages, but other data could be also shown.

In general, participants appreciated the tool. Once they practiced a bit with the tool, they did not have problems in interacting with it. Two participants remarked that the demo presented in the video is too short. Actually, they could stop the video or rewind it but they did not. They also said that this was not a big problem since the HCI researcher supplemented the video with some comments when requested. However, this is suggesting us to revise the video in order to provide a better description.

V. CONCLUSIONS AND FUTURE WORK

A novel visualization technique and a tool that implements it have been presented in this article. The technique uses circular representations to help people understand the activities performed by other team members during the day, in order to provide information about their availability.

The tool can be generalized to visualize various activity traces in different contexts, such as sensor data, work shifts and other activities going on during 24 hours. In particular, the focus group indicated possible use of CBP in collaborative development environments currently on the market, as well as in code versioning systems.

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