Metrics for Cooperative Systems

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ABSTRACT
This paper proposes performance indicators and metrics for the analysis of shared workspaces. We investigate user activity in various electronic workspaces of a shared workspace system and compare these on the basis of the proposed metrics: activity, productivity and cooperativity. Based on these results we further investigate the intensity of cooperation on shared documents. The investigations show that the proposed metrics permit an identification of the current cooperation status of a workspace as well as a classification of workspaces and benchmarking of the cooperation maturity.

Categories and Subject Descriptors
H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – Asynchronous interaction; Web-based interaction; Collaborative computing; Computer-supported cooperative work.

General Terms
Measurement, Performance, Experimentation, Human Factors.

Keywords
Metrics, evaluation, cooperativity, shared workspaces, cooperation analysis.

1. INTRODUCTION
Electronic media for communication and collaboration has been used for many years in business. Although there are critical considerations whether these media have a positive impact on the productivity of employees [4, 5], there are many advocates for the use of modern media cooperation. For knowledge workers [7] and virtual teams [8] groupware systems in general and especially shared workspace systems are indispensable in the context of today’s work [20]. In order to make a statement about the use of the systems and in particular on the productivity and the cooperativity of the actors within these systems, it is necessary to identify indicators that meet the requirements of operational performance measurement systems [19].

Previous evaluations over workspace systems were intended to gain knowledge about a specific system, with the question in mind: how is it used? By using these statistical evaluation methods, these systems have been improved and developed [1, 9]. But, these results are not yet used to characterize groups and to make a statement on their cooperation.

Social networks and their analysis are well researched and widely used [18, 23]. The social network analysis (SNA) is a method of social research and defines for example the edge density metrics, node degree centrality and clique analysis. The statements of these numbers refer to individual actors within the network, their relationships with each other and also to the entire network. Some approaches already exist to adopt this kind of analysis for groups and shared workspaces [10, 16]. The focus of the SNA lies in the description of the static network. Therefore, dynamic processes and activities of the members are not considered.

Another field of investigation is the classification of individual participants into productive workers and so-called lurkers [13, 15]. The classification of knowledge workers in these role categories is based on the performed actions. The decisive factors are both quantitatively and qualitatively and serve the productivity evaluated [7]. According to Drucker, there are six factors that affect productivity: (1) knowledge of the task, (2) knowledge and self-organization, (3) continuous innovation, (4) continuous learning and teaching, (5) the quantity and quality of work, and (6) identification with the company. These factors put their focus on an individual knowledge worker and are difficult to measure. It is obvious that most of the results of knowledge workers arise in a group in which each group member occupies one or more specific roles [21].

The metrics proposed by Koch and Richter [12] are suitable for measuring the success of the introduction of social media in the enterprise and expand the perspective from an individual to a broader view of the whole group. The mentioned figures are e.g. the change of the communication behavior (number of emails), number of documents, activity, level of participation in individual documents, degree of crosslinking of employees and employee satisfaction. The use of these indicators is often limited to a before-and-after comparison in the introduction of tools to determine the effect on the behavior of a group. Although a large body of quantitative research on Wikis and in particular Wikipedia exists, a measuring and benchmarking approach for the performance history of a group in a shared workspace environment is missing. In [14] 188 communities are analyzed to investigate the use of social media within different communities. This study is primarily based on a comparison of the different media types produced by the community members. Our research extends this by focusing on the cooperative activities performed by the group members.

The aim of this work is to define meaningful metrics that enable comparability and characterization of different workspaces and the observation of these over time. It is obvious that cooperative work is not happening within a single system, but rather in a set of systems. Other studies have shown, that the tools used for collaboration are very diverse [9]. The used tools range from e-mail, telephone conferences, collaborative editors, to lightweight specialized tools, such as Doodle. The use of all these tools happens in parallel within a work context. All these activities, as well as the physical cooperation in the same room, cannot be taken into account in the approach presented here. Therefore, the
authors limit their view on a single monolithic system that allows covering a huge amount of cooperation log file data, but with the knowledge not being able to capture all types of cooperation. The considered system is BSCW, a shared workspace system which will be presented in the following chapter. Chapter 3 defines the proposed indicators and metrics. In chapter 4, we present the result of applying the metrics to different workspaces.

2. SHARED WORKSPACE SYSTEMS

The shared workspace system BSCW (Basic Support for Cooperative Work) is a groupware that supports collaboration of several users on the internet [2]. The BSCW system is developed as a groupware system to support distributed work since 1995 at Fraunhofer FIT (former GMD FIT) and the spin-off OrbiTeam Gmbh & Co KG. The focus of the system lies on the self-organized coordination of distributed teams through a shared workspace. BSCW offers extensive facilities for document management, for registering and managing users and groups, discussion forums, as well as calendar and task management. Currently, about 1,000 servers of BSCW have been installed worldwide and the fifth major version has recently been released. The number of users is estimated at over 1 million. On the public server operated by FIT (http://public.bscw.de) more than 200,000 users are registered.

The BSCW system captures and stores all user actions on shared objects to provide users the information on the collaboration history and the current object state. Among additional technical details, the following meta-information is logged for each user action:

- **Timestamp** of the certain action
- **Action type**, e.g. read, create, modify, versioning, delete, etc.
- **Object ID**, unique identifier of the target of the action
- **Object type** of the target, e.g. document, folder, etc.
- **User ID**, unique identifier of the user performing the action

This information is provided by BSCW within the user interface by corresponding icons, but it can also be downloaded as a CSV file (comma separated values). This makes it possible to evaluate the behavior of cooperation in a workspace for an extended period of time.

For the analysis described in this article several workspaces were selected with different characteristics according to the different application domains of BSCW:

- **Project related workspaces (P)** serve the organization of cross-organizational projects. These are typically national or international research projects with 5-20 partners and a total of 10-70 project members over a period of several months or a few years.
- **Organizational workspaces (O)** support the cooperation within a specific department of an organization over several years.
- **Task related workspaces (T)** support the completion of a specified task, such as exchange of documents for a course over a short period of about six months or the joint development of a paper or a proposal.

We have selected these types of workspaces because they represent the major application domain of the shared workspace platform [9, 20].

3. NUMBERS AND METRICS

The indicators and metrics developed in this work are based on the participant-artifact-framework [6] and the meta-model of cooperative systems [11]. For the data analysis we transform the log data into the Activity Streams format [22], which shows a specific event at a specific time with its **actor**, a **verb**, an **object** and a **target**. By using this open format, it is also possible to analyze event data from other systems and to compare them with those of BSCW at a later stage of research. The log data of BSCW is exported as comma separated values (CSV) per workspace and then converted to the appropriate format. Different workspaces are first analyzed individually and then compared with each other.

For each work area elementary metrics are determined first. These include the duration of the activities or the project (in days), the number of active members, the number of objects or documents in the workspace and the number of individual events. These events are divided into three different categories: create, edit, and read (cf. Figure 1). This categorization achieves an abstraction in order to enable an adaptation of these metrics to other systems. createEvents are events in which people invest objects or documents. People who create the objects have the role of an author. editEvents are events in which a person modifies an existing object. A distinction is made here between changes to the **metadata** (name, description, tags, etc.) of the object, and the content of the object. People that edit the objects have the role of an editor. readEvents are events in which people consume objects or documents. The role of these people is called reader.

![Figure 1. Model of cooperation](image)

Three basic metrics were derived from the ratios: activity, productivity and cooperativity.

The activity metric describes the overall activity within a workspace: sum of all actions in a workspace per member per day on average.

\[
\text{activity} := \frac{\text{# events}}{\text{# members} \cdot \text{# days}}
\]

The productivity metric shows the number of productive activities, i.e. how many objects or documents have been created per member per day on average.

\[
\text{productivity} := \frac{\text{# createEvents}}{\text{# members} \cdot \text{# days}}
\]

The cooperativity metric describes the degree of cooperation, i.e. how many edits per member have been performed per day on average.
cooperativity := \frac{\# \text{editEvents}}{\# \text{members} \cdot \# \text{days}}

The above mentioned metrics are typically represented on a time basis. Dynamic considerations of the workspaces are playing a major role in projects. They allow an assessment of the nature of the workspaces and the group of employees. The metrics can be applied to any time interval (days, weeks, months, years) or even over the whole project duration. Our evaluations have shown that these values have a high variance over a longer time period. Thus shorter intervals are more useful for monitoring and evaluation.

In addition to these three basic metrics, additional metrics were developed to investigate the cooperative behavior on the objects in a workspace. The division of labor metric considers the allocation of activities to members and investigates the question: "What percentage of the workspace activity is performed by what ratio of active people in a workspace?" This metric is presented in a diagram with the axes of people and activities, in each case in per cent, so that a normalized representation can be achieved. This allows the comparison of different workspaces.

The responsiveness of a workspace answers the question: "After how many days is a certain percentage of the documents at least once considered or processed by a person (besides the author)?" This metric shows on the one hand how quickly members react on created objects of others, but also what percentage of the objects are never read. In the following section, we apply the presented metrics on different workspaces.

4. RESULTS AND EVALUATIONS

To apply and evaluate the usefulness of the metrics we analyzed ten different workspaces. Four belong to the category of project workspaces (P), three to the category of organizational workspaces (O), and three to the category of task related workspaces (T). The criteria for the selection of these workspaces were:

- Content: the workspaces contained a considerable amount of shared documents
- Group size: all workspaces had a group size of more than 40 people from different organizations
- Duration: all workspaces were in used for at least 2 years.

Applying these criteria we ensured that our analysis is both based on a broad spectrum of data as well as on longitudinal data. A total of nearly 50,000 events on nearly 7,500 objects from more than 600 persons were analyzed, which have occurred in different lengths of time between six months and several years.

Table 1 shows the basic data of the investigated areas. P1-P3 are medium sized projects with several project partners, whereas P4 clearly is a larger project. Similarly, O1 and O2 workspaces are within smaller working groups and O3 is a workspace of an entire organization area, which includes three working groups. T1-T3 are workspaces of lectures.

In the remaining of this section we analyze the event data of these workspace by different criteria and metrics.

4.1 Distribution of read, create and edit activities

The individual workspaces also differ in the type of events (Figure 2). As introduced above, we distinguish between three event types (create, edit, read).

<table>
<thead>
<tr>
<th>Workspace</th>
<th>People</th>
<th>Objects</th>
<th>Events</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>55</td>
<td>593</td>
<td>3139</td>
<td>981</td>
</tr>
<tr>
<td>P2</td>
<td>47</td>
<td>384</td>
<td>1465</td>
<td>1840</td>
</tr>
<tr>
<td>P3</td>
<td>52</td>
<td>814</td>
<td>4153</td>
<td>923</td>
</tr>
<tr>
<td>P4</td>
<td>105</td>
<td>1668</td>
<td>10427</td>
<td>2493</td>
</tr>
<tr>
<td>O1</td>
<td>32</td>
<td>74</td>
<td>390</td>
<td>3928</td>
</tr>
<tr>
<td>O2</td>
<td>9</td>
<td>57</td>
<td>182</td>
<td>497</td>
</tr>
<tr>
<td>O3</td>
<td>247</td>
<td>3749</td>
<td>22108</td>
<td>4547</td>
</tr>
<tr>
<td>T1</td>
<td>28</td>
<td>48</td>
<td>549</td>
<td>238</td>
</tr>
<tr>
<td>T2</td>
<td>89</td>
<td>82</td>
<td>730</td>
<td>553</td>
</tr>
<tr>
<td>T3</td>
<td>27</td>
<td>18</td>
<td>298</td>
<td>411</td>
</tr>
</tbody>
</table>

Figure 2: Ratio of events for each workspace

The results of the event type analysis by proportion become more visible by the representation as pie charts in the following figure.

Figure 3: Average event ratio for project workspaces
Figure 4: Average event ratio for organizational workspaces

Figure 5: Average event ratio for task workspaces

Figure 6: Activity, Productivity and Cooperativity of a project workspace over a period of 24 months. (Each group of 3 bars representing one month)

4.2 Activity, Productivity and Cooperativity

In the previous section we introduced activity, productivity and cooperativity as cooperation metrics. Figure 6 presents the monthly analysis of the activity, productivity and cooperativity metrics for a large project workspace over 24 months.

It can be easily recognized that the values have a high variance. Actually the maximum value is 1.5, but the presentation is clipped for better readability. The fact that phases with stronger or weaker activity exist is hardly surprising for such a long term project. Focusing on a single metric such as productivity provides an indication of that metric over time, but it is not possible to identify a characteristic pattern.

Table 2: Working situations and corresponding metrics

<table>
<thead>
<tr>
<th>Situation</th>
<th>Activity</th>
<th>Productivity</th>
<th>Cooperativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archive</td>
<td>~ (P)</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Co-Creation</td>
<td>high</td>
<td>&lt; (C)</td>
<td>high</td>
</tr>
<tr>
<td>Re-Use</td>
<td>N*(C)</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Deadline</td>
<td>high</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>No Activity</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
</tbody>
</table>

In the archive situation, users produce a lot of content that is not further edited nor read by many other users. Thus the activity
level is almost equal to the productivity level and the cooperativity level is low as not many edit events are produced. Such a situation does not appear in Figure 6.

In a co-creation phase the number of edit events increases resulting in a high cooperativity. The productivity level is actually below the cooperativity level as users concentrate more on the cooperation of existing content than the production of new. The activity level is also high since users need to read other users content before they start editing it. We can find a typical co-creation month at position (3) as well as at the project start (1st column bar) in Figure 6.

A situation in which the productivity level is high while the activity is significantly higher than the productivity and the cooperativity is low, indicates a phase in which a lot of content is produced and read by many users, but not further edited. This indicates a phase of information distribution and re-use (1).

A phase in which all metrics are high is likely to correlate with a deadline situation in which all project members become active in producing, reading and contributing (editing) content. We can find such a situation at position (2) which actually correlates to a real project review date. The fact that a re-use phase (1) precedes the deadline phase (2) in Figure 6 can be explained by the fact that the project members first start reading the existing content to become up-to-date before they start contributing new and working on existing content.

We can learn from this analysis that a situated and comparative analysis of the activity, productivity and cooperative metrics is useful to identify specific cooperation patterns and their corresponding project phases.

Using the data gathered for this analysis we further calculated the percentage of active, productive and cooperative days in Table 3.

<table>
<thead>
<tr>
<th>Table 3. Active, productive and cooperative days of the project with and without weekends.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active days:</td>
</tr>
<tr>
<td>Productive days:</td>
</tr>
<tr>
<td>Cooperative days:</td>
</tr>
</tbody>
</table>

Actually only at 20%-26% of all working days the project members produced new content or have been cooperatively working on the content, while definitely on more every 2nd day activities took place.

### 4.3 The division of labor

After the investigations of the proposed cooperation metrics we analyzed the division of labor within the workspace. For this purpose we calculated the ratio of the events that are produced by a certain ratio of users. The result is shown in Figure 7 to Figure 9.

The division of labor is relatively identical for the different project and organizational workspaces (Figure 7, Figure 8). It is interesting to note that approx. 20% of the group members are responsible for 80% of all events. On the other hand, the figures also indicate that already 70-80% of the members produce almost 100% of all events. The consequence is that 20-30% of all members are almost not active at all. A possible reason for this observation is that often people are invited into a workspace similar to being addressed by cc: in an email. I.e. they are receiving access to the workspace “just in case”, i.e. as observers or to prepare for these case that they need to become active in the project. Another reason is that project members often change between projects while their membership in past project workspaces is not revoked.

The analysis of task oriented workspaces yields a flatter curve (Figure 9) which indicates a more even division of labor among the participants. This can be explained by the fact that in this specific case were these workspaces were used to organize a lecture the participation and contribution by the students was more evenly distributed as in the project or organization workspaces which furthermore provides a good indication of the students’ engagement.
Figure 9: Division of labor in task specific workspaces
The division of labor analysis cannot easily be used to classify workspaces as in the previous sections. However it provides an interesting insight into the group structure and their participation in the cooperation process. The steeper the curve, the less equal is the division of labor. This indicator can be used to evaluate the group structure and membership.

The findings of the division of labor analysis are confirmed by analyzing the individual contribution of the workspace members. Figure 10 presents on the x-axis the 20 most active users of the 4 different project workspaces. In total these workspaces had a membership count between 43 and 62. The y-axis shows the ratio of the activity for these users.

Figure 10: The long tail of user participation
We see a steep drop from the most active to the 5th most active user who contributes approximately 5% of all activity events. From then on, the participation drops slowly and beyond position 13 the activity level corresponds to user who only very occasional became active in the shared workspace.

A more closer and user specific look at the participation confirms the findings of M. Muller in [13]. Among the 4 project workspaces we could identify 27 users who participated at least in 2 different workspaces.

For each user we calculated the activity position within the respective workspace. This position was then normalized using the total numbers of users in the workspace to enable a comparison. The result of this analysis is shown in Figure 11.

Figure 11: Variance of activities for user who participated at least in two workspaces
The x- axis lists the users anonymized by a user id. The y-axis indicates the normalized position in the activity list, were 0 indicates a high activity ranking and 1 a low activity ranking. The graphic demonstrates that at least 50% of the users have a high variance of their activities in different workspaces, i.e. they are very active in one workspace (~0.1) and almost not active in the other workspace (~0.7). This very much confirms the findings in [11] that the user participation is determined by the situational disposition and not simply by the fact of a general user attitude.

4.4 Responsiveness within a workspace
Another important indicator of a workspace and its associated group is its responsiveness. We determine the responsiveness of a workspace as the duration until a certain percentage of documents has been part of an activity. The following figures show the responsiveness as a graph in which the x-axis denotes the days after creation and the y-axis the percentage of read documents. The curve then indicates the ratio of documents that have become part of an activity (mostly read activities) within the range of days.

The responsiveness of project (Figure 12) and organization-related (Figure 13) workspaces differ only slightly. In both cases the workspace members respond within the first day on 30% to 45% of all objects. I.e. 30-45% of all objects become part of an activity within the first day. The steep start of the curve can be considered as the cooperation phase in which several users become active by reading or contributing to an object. After approximately one week the curve becomes more shallow indication a phase in which objects turn to archives. Further activity is them often initiated by a search by explicitly pointing users to the object. Both types of workspaces reach a response rate of 50% to 75% of the objects within 30 days. In turn this means that 25% - 50% of the objects have never been used during this period. The higher this value is, the higher is the archive nature of this workspace.

1 This value is calculated by \( \frac{\text{activity-position}}{\text{number of workspace members}} \)
The division of labor as well as the responsiveness analysis indicates that the shared workspaces contain a significant number of objects that are never read by any user of the group nor become part of a cooperative activity, i.e. they are only read by other users but they are never edited and revised.

Therefore we performed a deeper analysis of the read and cooperation activities per object. The results are shown in the following table.

**Table 4: Ratio of objects that become part of an activity**

<table>
<thead>
<tr>
<th>Workspace</th>
<th>% of read documents</th>
<th>% of revised documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>84%</td>
<td>34%</td>
</tr>
<tr>
<td>P2</td>
<td>91%</td>
<td>28%</td>
</tr>
<tr>
<td>P3</td>
<td>87%</td>
<td>11%</td>
</tr>
</tbody>
</table>

We can learn from Table 4 that between 84 and 91% of all created documents are read at least once by another user. Furthermore between 11% and 34% of all documents are revised, i.e. they became part of a cooperative activity. This indicates that the shared workspaces are mainly used as information and document sharing tools and less as a cooperation media in which documents are produced cooperatively. From our experience with the system we can identify two reasons for this observation. The first is that often the cooperative document production phase takes place outside of the system using email as the primary exchange media. Only when documents have reached a more stable status they are then shared with the overall project. The second reason is indicated by the ratio of revised documents on P3 compared to P1 and P2. Actually the ratio of revised documents in P3 is less than 50% of the other workspaces. P3 represents a project in which the majority of users were not IT-literate. They also used a cooperation platform for the first time. The membership of P2 and P3 consisted mainly of IT-professionals who are experienced in collaboration. Thus these metrics can also be used to determine the maturity of a user group with respect to the use of cooperation tools and platforms.
5. CONCLUSION AND OUTLOOK

This paper proposes several new metrics for the analysis of shared workspaces and it applies these metrics on a large body of activity logs produced within an operational shared workspace platform over a period between 2 and 3 years.

The quantitative analysis demonstrates that different workspaces of the same category often produce similar values, while they are different between the categories. Thus the following observations can be made: The statistical analysis of the group behavior in a workspace can be used to indicate the type of usage. This can trigger appropriate configurations or adjustments to the system. Furthermore we have shown that the combined consideration of the proposed metrics activity, productivity and cooperativity yields interesting insights into the current cooperation situation of a workspace such as a re-use, archival, co-creation or deadline phase.

The investigation of the division of labor lead to the interesting finding that the use of shared workspaces follows the Pareto principle [3, 17] (80–20 rule). Thus, we found that 20% of users perform 80% of the activities. Furthermore the cooperative activities only took place on 20% of the days of a cooperative project in a workspace. In addition the analysis of the user behavior across different workspaces confirmed Mullers finding from the analysis of communities with respect to the situational disposition between been a lurker and a producer.

The responsiveness analysis clearly shows that we can distinguish between a cooperation and an archival phase for shared documents. It is interesting to note that the cooperation phase has a typical duration of 5-7 days. The subsequent analysis of the ratio of objects that become part of an activity shows clear differences between workspaces used by unexperienced and more experienced users.

These finding can now be used to inform the design of shared workspace systems and even cooperation support systems in general. Today, most shared workspace systems provide visual representations to indicate recent activities on shared documents such as the awareness icons in Figure 15 or on the presence or activity of a single user.

In a next step we will design appropriate means to visualize and present this information within the user interface of the shared workspaces system. It will be interesting to see whether this feedback will have effects on the individual and group behavior.

We hope that these studies and the proposed performance indicators and metrics help to understand the cooperative behavior in shared electronic workspaces. In the next step we will extend the studies to other workspaces, with the aim to obtain a broader data base for the determination of metrics of shared workspaces.

Often organizations that apply cooperative systems require baseline data to benchmark their own behavior. The research and quantitative results presented in this paper provide a first step towards this baseline. If the intended usage of a work space is known, a comparison of the workspace metrics with the benchmark data provides an interesting insight in the cooperation maturity of a group and its organization. Appropriate training or change management processes to improve the team and group collaboration can then be triggered based on solid indicators.

6. REFERENCES


Figure 15: Different awareness icons of BSCW that indicate recent user activities

Based on the proposed metrics it becomes possible to indicate the overall behavior of a group as well as the current cooperation situation of a workspace. This can include indications of:

- The type (project, organizational, task-oriented) of workspace based on the ratio of the recent event types (Figure 3 - Figure 5)
- The current working situation of a group based on a comparative analysis of the metrics (Table 2).
- The structure and homogeneity of a group based on the analysis of the division of labor (Figure 7 - Figure 9)
- The time until which users can expect a reaction of the group on new contributions based on the responsiveness analysis (Figure 12 - Figure 14).


