Analysis of Virtual Workspaces

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Abstract

While traditional workflow management systems have proven useful in supporting well-defined organizational processes, they are less suitable for the support of less well-defined, emergent processes. These kinds of processes are better supported by systems which are based on the notion of workspaces. The research prototype LiveNet, which allows workspaces to be defined and supports their dynamic modification and evolution, has been developed and successfully applied in a number of domains. Based on the experiences with LiveNet, current research is focused on analyzing the structures supporting cooperation defined by workspace system users. Such an analysis can reveal structural deficiencies which can be brought to the users' attention. It can also aid the accumulation of a library of successful structures for later reuse. Finally, it can aid in extracting personal styles or preferences from observed structures which can be applied in creating new ones.

1. Introduction

Traditional workflow management systems have been successfully applied in many organizations. They effectively support a large variety of well-defined, repetitive processes, what we term production processes. Recently, however, there has been a trend from workflow to workspace systems which aim to support the less well-understood and more fluid processes which we term emergent processes. Because of the nature of emergent processes, ease of process evolution as well as communication among actors in a process assumes great importance in workspace systems.

However, very little is known about what constitutes a good workspace. What are the elements a workspace should be made up of? What is a good size for a workspace, in terms of the number of people and objects contained in it? Is it beneficial for workspaces to be tightly connected or should they be independent of each other? Are there structural patterns which are particularly successful in workspaces? These are some of the issues which our research is currently addressing.

The following section describes a model of workspaces which is designed to support emergent processes. In Section 3, the LiveNet prototype workspace system is introduced. Section 4 explores the issue of workspace structure addressed above. Finally, conclusions are presented in Section 5.

2. Workspaces

Physical cooperation takes place in physical space where all necessary tools, items and people are assembled for the task at hand. For virtual cooperation, a virtual place provides the substitute. Fitzpatrick et al. term this a locale [4]. Harrison and Dourish confirm the importance of place rather than space in collaborative environments; to them, a space provides the opportunity for collaboration which is realized when the space is appropriated by its users and then becomes a place [5]. We have developed a model of workspaces which serve as virtual spaces. Workspaces are dynamic structures which allow continuous modification and evolution and thereby allow their users to turn them into places for collaboration. Their aim is to support emergent processes which require this high degree of flexibility.

Very little may be known about an emergent process in advance except for its general structure: the main activities, roles and some major artefacts it consumes/produces. Consequently, a workspace model must allow a workspace to be initially defined just in terms of these general features. Later, however, as the process is being executed within the workspace, more process requirements emerge and more details need to be added to the workspace. For instance, it

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may be necessary to spontaneously start a discussion among
the members of a group, or to add a light-weight workflow
structure to certain activities, or to adapt the governance
structure applying to a specific role in the workspace, etc.

The main elements which define workspaces in our
model are: roles, actions, artefacts, message types, and
message rules. These are described below:

- **Roles** refer to the organizational entities involved in the
  workspace, e.g. a product manager. Roles are assigned
to participants in a workspace, i.e. to individual people.
A person never acts in a workspace just as themselves
but always as some organizational entity. This is con-
sistent with models of organized activity such as Holt’s
which state that every action is doubly performed, or-
ganizationally and personally [7]. The assignment of
participants to roles links the organizational and per-
sonal performers of actions.

- **Actions** are user-defined performatives. They can
  be grouped into two types: solo actions which are
  performed by a single action performer (a single
  role and participant); and interactions which involve
  multiple roles and/or participants. Interactions may
  be action-oriented such as a joint editing task, or
  communication-oriented such as a discussion.

- **Artefacts** are any objects which are consumed or pro-
duced in an action. These are usually documents of
  various types such as text, drawings, graphic images,
etc.

- **Messages** are short text strings which are exchanged
  between two roles to signal the occurrence of some
  event. The sending and receiving roles may reside in
  the same or in different workspaces. Messages have a
defined *message type* which is associated with, and
unique within, the workspace.

- **Message rules** establish mappings between messages
  and roles in a pair of workspaces (or within a single
  workspace if source and destination workspace are the
  same). They define which source message from which
  role in the source workspace is transferred into which
destination message for which role in the destination
workspace. Message rules in conjunction with mes-
sage types support light-weight workflows. Both mes-
sage rules and message types may be defined at any
point during process execution.

In addition to the above elements, workspaces define a
governance structure which assigns a set of workspace per-
formatives (i.e. built-in commands, such as “create a new
role”), actions (i.e. user-defined commands) and artefacts to
a role.

The relationship between the above elements is ex-
pressed in a meta-model in Figure 1.

Emergent processes can be expressed diagrammati-
cally using the rich picture notation originally intro-
duced by Checkland [1], and subsequently augmented by
Hawryskiewycz [6]. This notation captures the main ele-
ments of an emergent process: roles, interactions and arte-
facts, and their relationships with each other.

As an example, consider collaborative research. In such
research, a number of major activities may be identified,
such as research planning, carrying out a number of subpro-
jects, carrying out a number of experiments, etc. For each
of these activities it may be known which roles and which
major artefacts are involved, but the details of each activity
may not be known in advance and may be left for later def-
inition. A rich picture representation of this sample case is
shown in Figure 2. The clouds represent interactions, the
rectangles artefacts, and the stand-alone text strings roles.
The lines linking roles and interactions signify involvement
of the roles in the interactions. The arrows linking artefacts
and interactions signify involvement of the artefacts in the
interactions: production or modification (if pointing to the
artefact), and consumption (if pointing from the artefact).
Only one subproject and experiment are shown in this fig-
ure for reasons of simplicity, but a real case would involve
multiple instances of each.

The rich picture shows for instance that the Research
Planning activity involves the roles Coordinator, Project
Leaders and Experts, and produces the artefact Research
Plans. As can be seen, some of the roles are involved in
more than one activity, and the artefacts produced by one
activity may be involved in other activities. That is, there is
some coupling between activities. Coupling will be further
discussed in Section 4.

A mapping between this process structure and a suitable
workspace structure can now be performed: activities in
the rich picture are mapped into workspaces, roles involved in a particular activity become roles defined in a particular workspace, and similarly artefacts in an activity become artefacts in a workspace. Thus the rich picture process representation has been mapped into the following:

- A set of workspaces \( W \): \( W = \{w_1, w_2, w_3\} \)
- Each workspace \( w_j \) consists of a set of roles \( R_j \) and a set of artefacts \( A_i \):
  - \( w_1 = \{R_1, A_1\} \)
  - \( w_2 = \{R_2, A_2\} \)
  - \( w_3 = \{R_3, A_3\} \)
- And each of the sets \( R_i \) and \( A_i \) in turn contains some roles and artefacts:

  \[
  R_1 = \{ \text{Coordinator, Project Leaders, Experts} \} \\
  A_1 = \{ \text{Research Plans} \} \\
  R_2 = \{ \text{Project Leaders, Experts, Researchers, Assistants} \} \\
  A_2 = \{ \text{Research Plans, Background Papers, Experiment Plans, Research Reports} \} \\
  R_3 = \{ \text{Researchers, Assistants} \} \\
  A_3 = \{ \text{Experiment Plans, Research Reports} \}
  \]

   Note the overlap between some of the role sets \( R_i \), and likewise between some of the artefact sets \( A_i \). If a role is involved in more than one workspace, it is a member of each workspace and needs to be defined in each. The same applies to artefacts.

3. LiveNet

Based on the ideas of workspaces outlined above, our research group has developed the prototype system LiveNet which provides the user with means for creating workspaces and defining the workspace elements described earlier.

LiveNet is implemented as a three-tier system: users work with a LiveNet client which runs as an applet from a Web page and which communicates with a LiveNet server. This server in turn communicates with a relational database management system in whose database the workspaces, their elements, and related items are stored. Because the LiveNet client is implemented as a Java applet, it essentially extends the scope of cooperation to that of the Internet—regardless of location of its participants.

All of the conceptual elements of the workspace model introduced in Section 2 have been implemented in LiveNet. The implementation of some of these elements, however, requires explanation. Artefacts in the conceptual model are implemented as two separate types: documents and background material. Although they both constitute objects related to an activity, there is a qualitative difference. While documents are either the direct inputs or outputs of an interaction, background material contain the assumed knowledge for carrying out the interaction. Another element which is implemented in a special way is the discussion. A discussion is an interaction, a sub-type of action. However, a discussion action also contains a record of the discussion, which is akin to a document. So discussions are hybrid: both action and artefact and are used in LiveNet in a way that is different from other actions.

When users create a new workspace it is initially empty, but they can add roles, participants, actions, etc. to it. To illustrate this, consider the collaborative research example originally shown in Figure 2. A user would start by creating the three workspaces, which would initially be empty. At this point, the workspaces are still spaces in the sense of Harrison and Dourish, and will grow into places as they are appropriated by their users and the knowledge about the collaboration develops. The user would next add all the workspace elements which are already known in advance, i.e. in the case of the research planning workspace, the three roles and one document (artefact) identified earlier. Participants (i.e. actual people) are also assigned to the roles. The state of the workspace at this point is shown in Figure 3. Finally collaboration can begin. Since this workspace is intended for planning a research project, one of the first tasks would likely be to discuss the scope of the project. For this purpose, a discussion is set up and participants can now engage in the discussion. This is shown in Figure 4. Once the collaboration is underway, other requirements will surface and new documents, roles, actions, discussions, etc. will be added dynamically.

As activities in a real work setting are often related to one another, so workspaces in LiveNet may also be related to one another. For example, a discussion whose topic pertains to the subject of several workspaces may span these workspaces and involve participants from among them. Another possibility is that artefacts such as documents may need to be shared among workspaces, in which case an artefact in one workspace can be assigned to a role in another workspace. Workflow requirements may ex-
ist such that when an activity in one workspace is completed or has reached a milestone, a message should be sent to another workspace as a notification. These and other relationships between workspaces are supported in LiveNet and thus allow more than simply a collection of independent workspaces to be set up, but rather interconnected workspace networks to be defined and to dynamically evolve together.

4. Workspace analysis

As our research group has been gathering experience with the use of workspace systems, several questions have surfaced:

- What makes a workspace a “good workspace”? What are the elements that should be included in a workspace, and in what quantity and proportion? Is there an optimal size of a workspace to effectively support cooperative work? If so, which workspace elements should determine workspace size (number of roles, participants, artefacts, discussions, etc., or any combination of these)?
- What influence do inter-workspace relationships have on the structure of a workspace? Should workspaces be set up differently if they are part of a tightly connected workspace network as opposed to stand-alone workspaces? If so, where should such differences lie?
- What are the criteria to decide when to spawn off a new workspace from one that grows too large? What parts should be spawned off? What parts should be included in both the old and the new workspace, and what parts should be kept in only the old or the new?
What connections should be maintained between the old and new workspace?

- Setup of workspaces can be time-consuming for complex workspaces or networks of several workspaces. How can past workspace experience be channelled into the setup of new workspaces?

- Can patterns of successful workspace structures be extracted from existing workspaces for later reuse, perhaps classified into different categories of use? Is it possible to distinguish a successful workspace from an unsuccessful one? More fundamentally, what constitutes success in the use of a workspace?

- How can personal preferences be accommodated in the setup of workspace structures?

We are planning to find the answers to some of these questions through an analysis of the data in the LiveNet database. Several different types of analysis are possible:

- **Static analysis**, which considers the structure of a workspace.

- **Dynamic analysis**, which considers the behaviour of a workspace. This behaviour can be further subdivided into two kinds:
  - *Workspace evolution*, which traces the history of the workspace structure, such as addition, modification and deletion of workspace elements.
  - *User interaction*, which traces the use of the workspace by its end-users, such as entering statements in a discussion forum, opening documents, etc.

The current LiveNet database supports static analysis and, to some extent, analysis of workspace evolution. We
are planning to add a log of user interactions to our database to enable full dynamic analysis.

Analysis of processes has already been carried out in the context of production processes [2, 8]. The underlying goal in these efforts usually is to identify inefficiencies in processes in order to replace a current process definition with a simpler one [3]. This is suitable for well-defined, repetitive production processes. As outlined in the Introduction, however, workspaces serve less well-defined and fluid emergent processes, and therefore such kind of process simplification is not applicable to workspaces. On the other hand, the simplification of workspaces and workspace networks may prove to be of value. Thus the nature of the analysis is fundamentally different and requires a different approach. We are currently developing a number of analysis methods and measures which are particularly designed for the analysis of workspaces. These are introduced next.

4.1. Workspace types

The first step in static analysis is to extract the workspace structure from the database, which can be achieved through a set of database queries. The structure can then be analyzed to detect the number and proportions of its elements. This can give an indication as to the type of workspace, that is what the workspace is being used for. For example, a workspace which is used exclusively for general discussion would typically only contain one or more roles, with two or more participants and a discussion forum (possibly with a large number of statements), but no documents, actions or other workspace elements. A workspace used for brainstorming would have a similar structure, but would usually also include a document for recording the outcome of the brainstorming session. This case is shown in Figure 5 (a).

In Figure 5, the large ovals labelled W represent workspaces and the objects they contain are their elements. These include roles (R), forums for discussion (F), documents (D), background material (B), actions (A), message types (MT) and message rules (MR). Two of these types of workspace elements are shown in varying sizes: roles are shown in a size proportional to the number of participants assigned to the role, and discussion forums are shown in a size proportional to the number of discussion statements they contain. Thus Figure 5 (a) shows that the discussion forum has a large number of statements, and that some of the roles have a larger number of participants than others.

Other types of workspaces are shown in the other three cases. A workspace for joint authoring would contain several participants (possibly in several roles), a number of background materials, a discussion forum, and a document which is the outcome of the activity. This case is shown in Figure 5 (b). A workspace which is being used for more workflow-oriented tasks would contain one or more message types and rules, one or more roles, and some actions. This case is shown in Figure 5 (c). Finally, some workspaces are being used for a mix of activities which can not be classified into any category, as shown in Figure 5 (d).

Through the analysis of a large number of workspaces, patterns such as those discussed above can be discovered. These can then be described in terms of their constituent components and their proportions to one another, and this information can be added to a database of workspace patterns for later use.

4.2. Static workspace measures

Apart from an identification of workspace type, a number of statistical measures can be derived from a workspace’s static structure which can aid in its analysis. Such kinds of measures are particularly suitable in discovering possible structural deficiencies. These measures are discussed next.

One possible problem which may arise in workspaces is that they may become overloaded with too many items, inhibiting collaboration. This may arise out of a poorly conceived goal for the workspace, when too many activities are assigned to a single workspace. Identification of this problem will be the first step towards its resolution. Two relevant measures can be obtained from a workspace to aid in this problem identification. Firstly, the absolute workspace density, AWD. For this, we define the following workspace properties:

- R = the set of a workspace’s roles
- D = the set of a workspace’s artefacts (documents and background material)
- A = the set of a workspace’s actions
- F = the set of a workspace’s discussion forums
- MT = the set of a workspace’s message types
- MR = the set of a workspace’s message rules
- P = the set of a workspace’s participants

Furthermore, let the cardinality of each of these sets S be denoted as CS, then:

\[ AWD = C_R + C_D + C_A + C_F + C_{MT} + C_{MR} \]

Informally, AWD indicates how many “things” have been defined or created within a workspace. It is not by itself useful in deciding whether a workspace is overloaded, but is used in conjunction with another measure, the mean workspace density, MWD:

\[ MWD = \frac{AWD}{C_P} \]

That is, the number of items in a workspace is related to the number of people dealing with these items. If the number is high, the users of the workspace may individually
experience cognitive overload, and it may be advisable to move some items into a separate workspace.

Structures of workspace networks may also have deficiencies. For example, a set of tasks may be too fragmented, each one having its own workspace when a more suitable structure would be to combine a number of them in a single workspace. This case is the opposite of the above case of overloaded workspaces. The impact of this problem on the user, however, is similar. It can cause a user to experience cognitive overload, not because of the individual workspace’s structure (which is simple), but because of the complex inter-connections between a large number of workspaces.

Two measures are relevant to aid in identifying this problem. The first is workspace coupling, WC. Let the following workspace properties be given:

\[ D_E = \text{the set of a workspace’s artefacts which has been assigned to roles external to the workspace} \]

\[ A_E = \text{the set of a workspace’s actions which has been assigned to roles external to the workspace} \]

\[ F_E = \text{the set of a workspace’s discussion forums which has been assigned to roles external to the workspace} \]

\[ MRI_E = \text{the set of a workspace’s message rules with a target role external to the workspace} \]

\[ D_I = \text{the set of other workspace’s artefacts which has been assigned to roles internal to the workspace} \]

\[ A_I = \text{the set of other workspace’s actions which has been assigned to roles internal to the workspace} \]

\[ F_I = \text{the set of other workspace’s discussion forums which has been assigned to roles internal to the workspace} \]

\[ MRI_I = \text{the set of other workspace’s message rules with a target role internal to the workspace} \]

Furthermore, let cardinalities be denoted as before, then workspace coupling, WC, is:

\[ WC = C_{D_E} + C_{A_E} + C_{F_E} + C_{MRI_E} + C_{D_I} + C_{A_I} + C_{F_I} + C_{MRI_I} \]

Workspace coupling expresses how strongly a workspace is related (coupled) to other workspaces, either through its own elements assigned to other workspaces, or through other workspaces’ elements assigned to it. An excessively high value for WC indicates that the partitioning of activities among workspaces may be sub-optimal.

A related measure which is concerned with workspace networks is workspace cluster size, WCS. It measures how large the neighbourhood of inter-connected workspaces is. Workspace cluster size is the cardinality of the set of workspaces which are transitively related to each other through assignments of artefacts, actions, discussion forums, and message rules.

Different combinations of values of the four measures AWD, MWD, WC and WCS indicate different potential problems in workspaces and their networks. For example, if AWD and MWD are low, but WC and WCS are high, the partitioning of workspaces may be too fine and it may be beneficial to combine several workspaces. On the other hand, if AWD and MWD are moderate, and WC is high, the number of workspaces may be good but the partitioning of activities among workspaces may be poor and a re-arrangement may be necessary. This case is illustrated in Figure 6, where ovals represent workspaces and arrows represent assignments of workspace elements among pairs of workspaces. While the given set of activities is partitioned into the same number of workspaces in both cases (a) and (b), case (b) requires a much greater number of inter-workspace relationships than case (a), due to a poor allocation of activities to the workspaces.

4.3. Applications of workspace analysis

We perceive several main areas of application for workspace analysis:

1. Revealing structural deficiencies. Workspaces which have an excessively high absolute and/or mean density may be overloaded and should be split into separate ones, if possible. Other structural deficiencies may also be discovered in workspace networks, and these deficiencies may be brought to the user’s attention with suggested remedial action. Given the user’s approval, the workspace system may then carry out this action.

Figure 5. Types of workspaces: (a) brainstorming; (b) joint authoring; (c) workflow; (d) mixed
2. Extraction of workspace patterns. Workspace structures are created to serve a specific purpose. If we can discover patterns of workspace structures and identify the area of application of these structures, we will be able to reuse these patterns in the creation of future workspaces. Through continuous analysis of workspace databases, over time a library of workspace patterns will be created. This can reduce future effort in creating new workspaces.

3. Adaptive workspaces. Workspaces can be constantly monitored to discover patterns in their evolution, and to match these against a library of existing evolution patterns. Once a match is found, it is likely that the workspace is evolving into a form similar to the one matched. The user may then be prompted whether to let the system adapt the current workspace into the form obtained from the library, thereby saving the user time in the customization of the workspace.

4. Workspace personalization. Through observation of an individual user’s workspaces, user preferences may be discovered. For instance, a certain user may always include a discussion forum for all the roles of the workspace (maybe for sharing news among its participants). Knowledge of such user preferences may be combined with the extraction of workspace patterns mentioned above: a new workspace may be created by reusing a generic pattern from a pattern library, and may subsequently be personalized by applying the user preference pattern to it.

As we continue to investigate workspace structures, other applications of workspace analysis will no doubt emerge.

5. Conclusions

This paper has discussed the application of workspaces in supporting emergent processes. Workspaces provide a context for cooperation without imposing a rigid process structure. They thereby offer a great deal of flexibility and the potential to dynamically evolve along with the collaboration carried out in them. The LiveNet prototype, developed in the Collaborative Systems Laboratory, implements a system of such workspaces which allows any Internet user to join into a collaboration through their Web browser.

An interesting and challenging research problem for workspace systems is to determine what constitutes a "good" workspace. The analysis of existing workspaces and their success in supporting collaboration will offer at least part of the answer. The discovery of cooperation patterns that are encoded as workspace structures in a workspace database, and the reuse of such patterns, appear as promising areas of application, and still require further research.

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References