Providing Awareness of Cooperative Efficiency in Collaborative Graphics Design Systems through Reaction Mining

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***Abstract*—Awareness of individual and group activities is critical to successful collaboration and is commonly supported in collaborative graphics design systems (CGDS). Awareness of cooperative efficiency visualized in fine granularity is valuable for finding out the bottlenecks in collaborative design process. However, little work has been done. In this paper we propose a novel intelligent cooperative efficiency evaluation mechanism via mining the reaction information. By visualizing cooperative efficiency, cooperators are enabled to concentrate on the most of controversial part of the cooperative work. Related algorithm that includes two key concepts: expectation and convergence is proposed. The mechanism and algorithm have been realized in our prototype system and are proved significantly promote the coordination efficiency.**

***Index Terms*—CSCW, collaborative graphics design systems, awareness, cooperative efficiency, reaction mining**

I. INTRODUCTION

Due to the meta-components' regularity and tasks' complexity, pattern design often requires collaborative working between members of a project team in several fields, such as textile printing and weaving industries. A typical project involves a group of geographically distributed users connected by a communication network, e.g., the Internet, who cooperate with each other by concurrently manipulating shared graphics documents. With the rapid development of CSCW technologies, the effective and high quality collaborative design tasks will be carried out in a seamless way.

Collaborative graphics design system [1, 2, 3, 4] is a special class of Computer-Supported Collaborative Work (CSCW) systems. Compared to traditional design work model, collaborative design work model makes full use of all the partners' creativity and imagination to produce more beautiful, fantastic patterns, through coordinating with each other. This has been validated a great help for the productivity.

Awareness, which highlight the information and knowledge sharing among cooperators, is central to successful collaboration. Awareness propagation is effective if the appropriate amount of information, relevant to the user's sphere of activity is delivered in a timely, unobtrusive fashion. In CGDS [1] people use workspace awareness not only to follow actions of others, but also to understand and respond to any changes others make to the workspace artifact. Nowadays, research on awareness mainly focuses on providing awareness techniques and tools to assist collaborative design job. A new standard is set for telepointers, and designers are allowed to greatly improve the support that groupware provides for real-time interaction over distance [13]. Stach, T. [14] provides co-present virtual embodiments to improve the awareness. Semantic awareness mechanism is introduced to avoid semantic conflict which tries to promote the efficiency of collaboration, as in [4]. However, little work has been done in mining the awareness information, quantitative analyzing and visualizing the cooperative efficiency state.

It is important for cooperators, especially the group leaders to check the efficiency of the graphics design and find out the bottleneck that influences the collaboration. Liu et al [15] provide several graphic information visualization methods including process line, task precedence graph, and etc. to show the process of collaboration task. Since the methods presented the state or efficiency of cooperative task with coarse granularity, people can hardly gain the knowledge of the design efficiency in granularity of design region and objects in workspace.

In this paper we propose a novel mechanism to evaluate and visualize cooperative efficiency through mining the information of reactions. In our CDGS the system will automatically process video images, processing face expression, furthermore take a judge of person's reaction toward the modified graphic pattern. Meanwhile the system will visually exhibit cooperative efficiency. This system is able to capture one's face expression. By video camera and face recognition techniques, we can distinguish one's reaction from other partners' drawing pattern objects between accept and refuse. And also we have a whole dynamic acceptability region. For any single object in the sharing workspace, the region will display the acceptability of our work members towards to it. Thus any member of cooperation in the workspace can be notified with current coordinative efficiency visually in granularity of region and drawing objects.

The rest of the paper is organized as follows: Section 2 depicts the architecture of CGDS, the artifacts and the hiberarchy of CGDS and the awareness in CGDS. Section 3 describes the awareness of reaction and the process of getting reactions. Section 4 presents the mechanism of cooperative efficiency awareness including evaluation and visualization. Finally, Section 5 concludes the paper.

II. BACKGROUND

A. *the Architecture of CGDS*

A replicated architecture [5], [6] that each site maintains a replica of the shared document is always adopted to obtain good responsiveness and unconstrained collaboration. With replicated architecture, local operations such as creating, deleting, modifying and etc. are issued and executed on local site immediately and broadcast to other remote user nodes. Each site needs to maintain the consistency of the graphics documents.

Based on such replicated architecture, a server is introduced in our CGDS as shown in Fig. 1. Acting as an coordinator, the server exchanges access rules, keeps the latest version for mutual awareness and consistency purpose. Besides, it processes the awareness information that comes from the distributed cooperative sites and issues related information back.

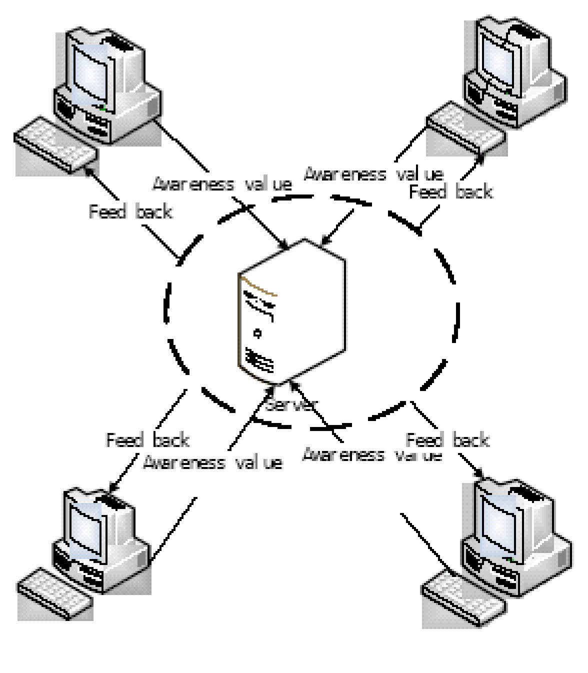

Figure 1. The architecture of CGDS

B. *Hiberarchy of the Graphics Documents*

In CGDS shared workspace provides its users with environment for collaborative editing over the computer network. Artifacts are those objects that consumed or produced in a document. The artifacts defined in this system can be presented in a hierarchical structure as shown in Fig. 2. In CGDS document can be defined as follows:

document ::= attribute | < layer | layer | …> | operation
layer ::= attribute | < drawgroup | drawobj | …> |
operation
group ::= attribute | < drawgroup | drawobj |… >
operation
object ::= attribute | operation

In Fig. 2. D stands for document, L stands for layer and O stands for object. G donates a group of objects that designers may edit them as a whole.

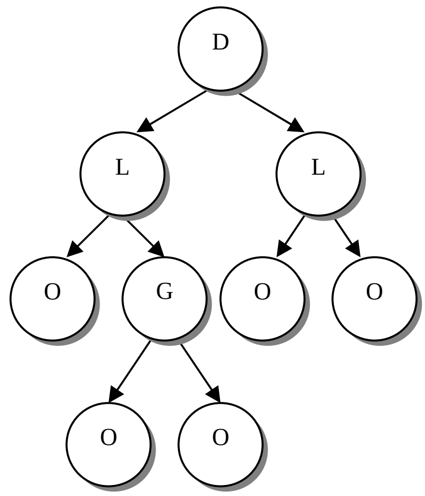

Figure 2. The hiberarchy of the graphics documents.

The graphic document can be separated into multiple drawing layers for the purpose to increase the parallelism of editing process. As the basic element in the document, object can either be graphics such as rectangle, ellipse, free drawing line and etc, image or text. When several objects are bound together, drawgroup is formed. Generally, operations act on the drawgroup influence all the related objects.

C. *Awareness in CGDS*

Awareness is an understanding of the activities of others, which provides a context for your own activity [7]. This context is used to ensure that individual contributions are relevant to the group's activity as a whole, and to evaluate individual actions with respect to group goals and progress. The information, then, allows groups to manage the process of collaborative working.

Prinz [8] identified two types of awareness: social awareness and task-oriented awareness. Social awareness refers to being aware of the presence and activities of users. By contrast, task-oriented awareness refers to being aware of the contributor and activities of tasks, e.g. being aware of the occurrence of certain tasks.

In CGDS awareness can mainly be captured and diffused through several media ways, such as workspace, audio, video, short messages, and etc. People observes the dynamic editing process that presented on the canvas, while at the same time may chat freely with cooperators and view their reactions to his design. Awareness helps to set up an virtual collaborative environment that may promote the coopertaive efficiency in CGDS.

III. AWARENESS OF REACTIONS

In cooperative work many phenomena have been described in terms of two basic principles: reaction and diffusion. Some researchers have found the mutual effect between the related awareness information and proposed a reaction-diffusion metaphor to deal with the interaction [9]. Reaction to cooperators' design action is deemed as an important awareness metaphor in CGDS [10].

Base on the empirical discovery, we designed our innovative system. Actually, when any member of collaboration group modifies the pattern, regardless of creating new object, changing color of existed object or other else, the other members will have some reactions. These reactions will come from partners' face expression, voice even typed words when they are chatting. In our previous work, although video, audio and chat chanel are used to help cooperation work between members, we do nothing with these precise awareness information.

A. Capturing Reactions

Face tracking and expression recognition techniques have widely been used in intelligent human computer interaction (HCI) applications. 2DFAP (2D face animation parameter) system is a combination of face detection for standard frames (where the face is frontal and upright) and facial feature tracking for other frames [11]. FAP has been used widely in facial animation for its good compression recently. Besides, the FDP and low level FAP constitute a concise representation of the evolution of the expression of the face. These parameters comprise of the information of eyebrow, eye, nose and mouth, and roughly reflect one's emotion, such as anger, joy, fulfillment, dislike, etc. In practice we use Support Vector Machine (SVM) to train these emotion models, and then classify them into different emotional categories. In our prototype system, smile may be captured and treated as the reaction of consent. On the contrary, expression like frowning may mean discontent.

B. Process of Capturing Awareness of Reaction

Object is the minimum editing unit as it is shown in Fig. 2. When any designer modifies the object (or objects) of existed pattern in the workspace, we trigger on our awareness sub-system to get reactions from other members through his face expression, voice, or other awareness channels. These reactions represent one's attitude towards these modified objects. Automatically our system will assign the reaction (satisfying, acceptable, dislikable, etc) a value which represents the member's attitude. Here we called awareness appraisal value (AAV). Although in the collaborative work, various people may play different roles, they may have different level of importance. And also depending on the different channels we get the awareness information, the format and quantity of these information will not be universal consistent.

So AAV will bring some specific data about awareness source (which channel do we get the appraisal?), importance (what role does he play in cooperation work?), object information (which objects arouse this reaction) and the real appraisal data, as it is shown in Fig. 3.

Next these AAVs at all sites will be sent to the president of the group. The president of the group will collect all the AAVs from other sites. In this stage, according to the weightiness of the partners and global information, the president will calculate the final appraisal value and inconsistent degree about the modified objects by the balance algorithm (we will describe it in later chapters). Finally he will send back the ultimate result to all members in this group, as it is shown in Fig. 1.

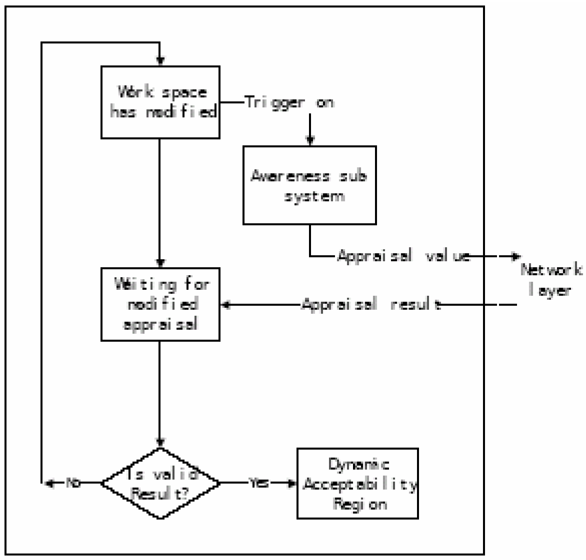

Figure 3. The process of capturing awareness of reactions.

IV. AWARENESS OF COOPERATIVE EFFICIENCY

A. Convergence Equation and Expectation Equation

Identifying congruence of cooperation work and determining the appropriate coordination mechanism to address collaborative efficiency is not a trivial problem [12]. Many stylized types of task dependencies and coordination mechanisms have been proposed over past several decades. Some people have proposed concept of "fit" which describes task dependencies and the coordination activities performed by individuals. Regretfully, this mechanism is not compatible with graphics design system.

In probability theory and statistics, the variance of a random variable, probability distribution, or sample is one measure of statistical dispersion, and the expected value (or mathematical expectation) of a discrete random variable is the sum of the probability of each possible. Here we want to define the coordinating degree to demonstrate the current cooperative efficiency, and the final compromised expectation of all members' attitudes. To some extent, the discrete degree of the different attitudes can represent the cooperative efficiency, and naturally the variance can describe this quantitatively.

So in our system the Convergence Equation is to present the inconsistent degree of all members' attitudes of modified objects. And Expectation Equation is to describe the expectation of final attitude through integrating all AAVs, as it is shown in Fig. 4.

AAV includes the following domains:

Attitude Domain (AD):

$a_i \in N$, which represents a kind of attitudes.

Awareness Channels Importance Domain (AC):

$c_i \in [0, 1]$, which represents a kind of awareness channels.

Members Importance Domain (MD):

$m_i \in [0,1]$, which represents the importance of the member in our group.

Supposed the number of system members' count is n, so the president will receive (n-1)*AAV (any member won't appraise himself):

$(AAV_1(a_1, c_1, m_1), ..., AAV_{n-1}(a_{n-1}, c_{n-1}, m_{n-1}))$

Expectation Value tries to describe the attitude value with the most frequency. We define the Equation as follows:

$$ExpectationValue(EV) = \sum_{i=1}^{m} \frac{c_i}{sum(AC)} \sum_{j=1}^{n-1} \frac{m_j}{sum(MD)} a_j \quad (1)$$

where,

$$sum(AC) = \sum_{i=1}^{n-1} c_i, \quad (2)$$

$$sum(MD) = \sum_{i=1}^{m} m_i. \quad (3)$$

According to upper definition, expectation value will belong to the real number, and we have $EV \in [\min(AD), \max(AD)]$. So, $EV = [EV]$.

	Member 1	Member 2		Member n-1
Channel 1			...	
Channel 2			...	
Channel 3			...	
	... ...	... ...	...	... ...
Channel m			...	

Figure 4. AAV data structure.

The simplified form of this equation is as follows:

$$ExpectationValue = E_{AC}(E_{MD}(AD)). \quad (4)$$

E means Mathematical expectation.

Inconsistent Degree tries to quantitate the convergence of all members' attitudes entirely. Naturally, the degree will reflect coordinating status of part of our work.

According to equation:

$$D(X) = E(X^2) - (E(X))^2, \quad (5)$$

we define the convergence Equation Similarly:

$$Inconsistent\ \ Degree = \sum_{i=1}^{m} \frac{c_i}{sum(AC)} \sum_{i=1}^{n-1} \frac{m_j}{sum(MD)} a_j^2 - \left(\sum_{i=1}^{m} \frac{c_i}{sum(AC)} \sum_{j=1}^{n-1} \frac{m_j}{sum(MD)} a_j\right)^2. \quad (6)$$

B. Global Awareness

Remember that every two modified action will arouse the awareness triggering on. After receive AVVs from all sites, we will have two statistics for any object involving the action, Expectation Value (EV) and Inconsistent Degree (ID). If we have n objects of the graphic pattern in the workspace, we will have a vector in the following format:

$$AwarenessVector(AV) = ((ev_1, id_1), (ev_2, id_2), ..., (ev_n, id_n)). \quad (7)$$

Correspondingly we also have

$$ObjectVector(OV) = (O_1, O_2, ..., O_n), \quad (8)$$

which represents the objects in our workspace.

From the global perspective, single object can not take the effect alone in the graphic design system. Essentially, all objects work together to convey the pattern sense to people's visual neural system. We try to capture these objects mutual visual interaction and give thorough description of global awareness information.

For three objects, our schema will explain in the following steps:

Step I:

Initially:

$$ObjectVector = (), \quad AwarenessVector = ().$$

Step II:

When first object has been created:

$$ObjectVector = (O_1), \; AwarenessVector = ((ev_1, id_1)).$$

When second object O_2 has been created:

Here we discuss according to the following two conditions:

i. If O_2 and O_1 are overlapped

If two objects are overlapped, people can not easily distinguish the impressions from them. Visually, if we appraisal one of them, our attitudes will definitely be impacted by the properties of the other. In other words, the two overlapped objects will take mutual influence and generate the visual effects together. So when this happened, we need to cut out the clipping of the overlapped part of the two objects. The intersectant part will be assigned as the child object of O_1 and O_2.

So we define the Transform Object Function:

$$TOF(O_i, O_j) = O_{ij} \tag{9}$$

O_1 and O_2 are the parents of new O_{ij}, which generated by TOF function. We simulate this procedure by using tree data structure. O_{ij} is on the level 2 layer.

We define the Transform Awareness Function:

$$TAF(ai_1, ai_2) = ai_{12}, \tag{10}$$

where,

$$ai_1(AwarenessInformation) = (ev_1, id_1). \tag{11}$$

Finally, we generate new and Object Vector and Awareness Vector, and insert O_{ij} and ai_{12} into them.

$$ObjectVectorSet = \{OV_{level1}(O_1, O_2), OV_{level2}(O_{ij})\} \tag{12}$$

$$AwarenessVectorSet = \{AV_{level1}(ai_1, ai_2)\} \tag{13}$$

ii. If O_2 does not intersect with O_1:

We just insert O_2 into $ObjectVector_{level1}(OV_{level1})$ and ai_{12} into $AwarenessVector_{level1}(AV_{level1})$.

$$ObjectsVectorSet = \{OV_{level1}(O_1, O_2)\} \tag{14}$$

$$AwarenessVectorSet = \{AV_{level1}(ai_1, ai_2)\} \tag{15}$$

So if O_i and O_j have common region,

$$TOF(O_i, O_j) = O_{ij}. \tag{16}$$

Otherwise,

$$TOF(O_i, O_j) = NULL. \tag{17}$$

Step III:

We will calculate the final cooperative efficiency according to the corresponding object information and level sequential order.

If we have n levels, and id_n

$$FinalCoordinatingEfficiency = \frac{1}{n}\sum_{1}^{n} id_n \tag{18}$$

Next when object 3 has created in the workspace, this will return to step1.

We will do:

1. $O_{13} = TOF(O_1, O_3)$ and $O_{23} = TOF(O_2, O_3)$, insert O_{13} and O_{23} into OV_{level2}.
   $ai_{13} = TAF(ai_1, ai_3)$ and $ai_{23} = TAF(ai_2, ai_3)$, insert O_{13} and O_{23} into AV_{level2}.
   Because object O_{12} has already been generated in the OV_{level2}, when O_3 is inserted. We need to calculate whether they have overlapped parts. If true, we will generate new level OV_{level3} and AV_{level3}.
2. $O_{123} = TOF(O_{12}, O_3)$, and generate OV_{level3}, insert O_{123} into OV_{level3}.
   $a_{123} = TAF(ai_{12}, ai_3)$, and generate AV_{level3}, insert a_{123} into AV_{level3}.

The upper example is shown in Fig. 5.

Generally:

$$ObjectVectorSet = \{OV_{level1}, OV_{level2}, ..., OV_{leveln}\} \tag{19}$$

If $O \in OV_{leveli}$, O must have following format:

$$O = O((l_1 l_2 ... l_{i-1}), l_i)$$

where, $l_i \in N, 1 \le l_i \le i, l_j \ne l_k$

This means:

$$TOF(O_{l_1 l_2 ... l_{i-1}}, O_{l_i}) = O((l_1 l_2 ... l_{i-1}), l_i). \tag{20}$$

Here we define:

$$l_1 l_2 ... l_i = subscript(O_{l_1 l_2 .. l_i}) . \tag{21}$$

According to this definition:

If an object's $(O_{l_1 l_2 .. l_i})$ subscript is $l_1 l_2 ... l_i$, the algorithm can be described as the following recursive format:

$$\begin{aligned}
&Generate(O_{l_1 l_2 .. l_i}) = \{\\
&\quad if \quad subscript(O) == l_1, return \quad O_{l_1}\\
&\quad else\\
&\qquad return \quad TOF(Generate(O_{l_1 l_2 .. l_i}), O_{l_i}); \}
\end{aligned}$$

Actually object $O_{l_1 l_2 .. l_i}$ in OV_{levlei} is the conjunct part of the following object sequence: $(O_{l_1}, O_{l_2}, ..., O_{l_i})$

$$ObjectVectorSet = \{OV_{level1}, OV_{level2}, ..., OV_{leveln}\} , \tag{22}$$

and then we create an object O_i :

For every OV_{levelj} , and for every $O_{l_1 l_2 .. l_i}$ in OV_{levelj} , $Generate(O_{l_1 l_2 .. l_j l_i})$, then we insert $O_{l_1 l_2 .. l_j l_i}$ into the $OV_{level_{j+1}}$.

By the same procedure we also can easily get:

$$AwarenessVectorSet = \{AV_{level1}, AV_{level2}, ..., AV_{leveln}\} \tag{23}$$

C. Visualizing Cooperative Efficiency

Visualization not only replaces good solid quantitative analysis, but also allows the quantitative analysis to be focused. Compared to facing with complex boring numbers in large data sets, visualization will enable us to understand more directly. In other words, visualization allows us to use our natural spatial/visual abilities to explore more information.

As described above, we have just illustrated two very critical concepts about cooperative efficiency, and explained our global awareness schema. Here we get two important sets: Awareness Vector Set and Objects Vector Set. The Awareness Vector Set includes the singer and the global collaborative efficiency information, meanwhile Objects Vector Set comprises of Objects (including generated virtual objects by our algorithm) self-information such as shape, position, size, etc. Based on these information, we create an area called Dynamic Cooperative Efficiency Region (DCER).

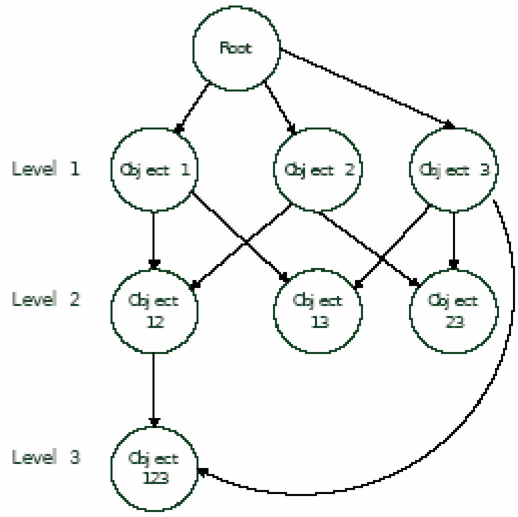

Figure 5. Objects Tree.

If ai_i is corresponding to O_i , and ai_j corresponding to O_j , and we have:

$$TOF(O_i, O_j) = O_{ij} , \tag{24}$$

$$TAF(ai_i, ai_j) = ai_{ij} . \tag{25}$$

DCER tries to visualize ai_i , ai_j , ai_{ij} , combining with the O_i , O_j , O_{ij} . This region called Dynamic, because it will be gradually transformed according to current cooperative efficiency dynamically. In our real-environmental system, we just map ai to a certain color. If $TAF(ai_i, ai_j) = ai_{ij}$, ai_{ij} will be an intermediate color between the two father colors, as it is shown in Fig. 6.

D. Experiment

We have done two experiments for contrast. First, we let these users use our previous system, which is not shipped on the new feature of efficiency awareness sub-system. Then we collect advices at the aspect of defects of our system, furthermore we ask the users if they are satisfied with the graphic pattern which just created by their team members. Second, we told them nothing about our new-featured system, we just assigned them the same task in the new system, and only told them the meaning that DCER conveys to them. We ask them the same question after the experiment. Results are shown in Fig. 7.

The result is not unexpected in our prediction. In the first experiment, although most people can accept the final graphic pattern moderately, many of them think the final result is not the real desired output of his aspiration. They all complain about the unnecessary conflicts with their partners, and the troublesome of understanding the intention of partners' drawing action. Meanwhile, most of

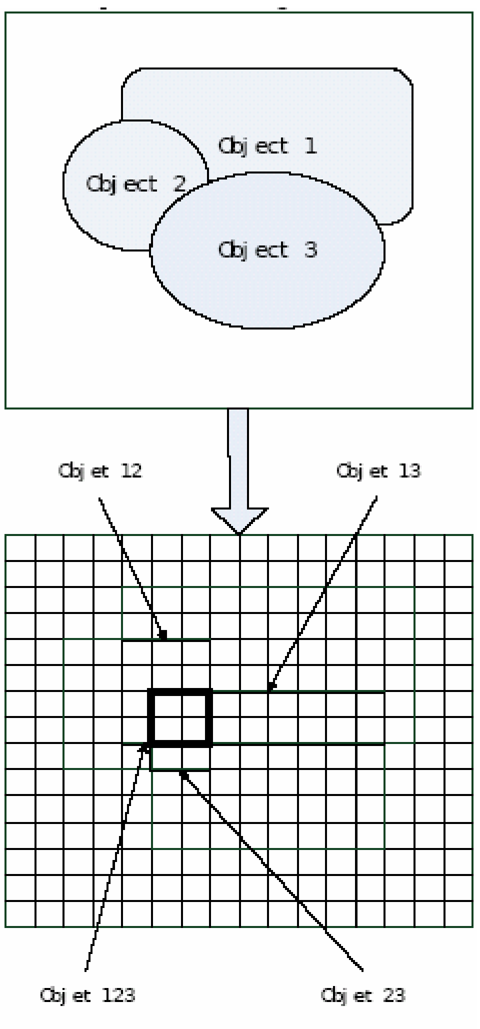

Figure 6. Visualization of three overlapped objects.

	Acceptiblity	desirability	conflicts	Cost-time
1	0.86	0.18	76%	38(min)
2	0.92	0.56	48%	31(min)

Figure 7. Contrast of two systems.

them refer to the lower efficiency of coordinating mechanism via video, and audio, because the noises from several information channels' background, many trivial things would disturb the user's concentration.

After the second experiment, more surprisingly, the users unanimously think the coordinating mechanism in the new system is more efficient than first one. Through the Dynamic Cooperative Efficiency Region they said they can easily focus on the area which need to be improved the most and can quickly get the feedback from others. They also said this coordinating mechanism help them with the global perspective of their work, and reducing the conflicts between members, as it is shown in Fig. 7.

V. CONCLUSION

Considering the characteristics of collaborative graphic design system, we provides cooperative awareness mainly focus on exposing the controversial parts in the common workspace and support them with the global perspective. By capturing the reactions of cooperators and mining the information behind the reactions, we presented the novel mechanism of evaluating the cooperative efficiency in granularity of drawing objects in collaborative workspaces. Related experiments demonstrate that it achieves the seamless system to promote the cooperative efficiency which means collaborators needn't to waste time on system coordination and communication through the traditional video or audio channels.

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