TELEPINUP SYSTEM: A CONTEXTUAL GRAPHICAL COLLABORATION TOOL FOR REMOTE DESIGN INTERACTION

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Abstract. This paper addresses a pilot study in proposing a series of interface design solutions as integrated parts of a virtual communication space prototype: Telepinup System, which intends to enhance dynamic and seamless experiences for distributed architectural design discussions through digital interaction. Aiming to support graphic-centered, nonlinear, and contextual way of visual-verbal communication suitable for design discussion, the prototype tool is developed to demonstrate various interface solutions and to be evaluated within the actual use contexts in two user experiments for its efficiency and effectiveness of underlying design criteria and proposed solutions. Interaction patterns during the experiments are recorded in the database and immediately visualized at the end of each test for participants to give instant feedback and for later analysis. The initial result shows that the collaboration between some critical interface solutions helps seamlessly synchronize graphical, verbal and social information exchange.

1. Introduction

In spite of the technical, social, and professional challenges that remain, remote design communication has been broadly adopted in both educational and professional environments as a result of technological advancements and logistical necessity. However, there remains a wide gap between the functionalities provided by generic and design communication tools and the real needs of remote design interaction. Our initial analysis of the actual conditions of design pinup and desk crit communication, as well as an evaluation of commonly used tools, revealed that these tools fail to consider (1) the context of design graphics, (2) the dynamics of communication patterns, (3) the communicative significance of instant and rich visual expressions, and (4) awareness information regarding co-participant activities and behavior relative to the presentation space – all factors critical to a fluent design discussion. Research in the past decade on CSCW (Computer Supported Cooperative Work) has consistently suggested the importance of these factors and identified related issues. For instance, Fischer argues that computer support for ongoing and collaborative design must provide representations of both intent and context in order for meanings to be communicated from speaker to listener over time (Fischer, Nakakoji, and Ostwald 1995). This implies that the relationship between user expressions and design artifacts such as graphic drawings should be continuously revealed to help enhance understanding. Greenberg concludes that support for workspace awareness can be a valuable and appreciable addition to a groupware system, but needs to be carefully designed with the consideration of tradeoffs between being well-informed about others' activities and being distracted from individual tasks (Greenberg and Gutwin 1998). He also argues our physical gestures for expressions are poorly approximated by a mouse cursor (Hayne, Pendergast,and Greenberg 1993) although it provides awareness information about a user's presence and activities, focus of attention, and degree of interest (Gutwin and Penner 2002). In spite of fruitful research results of found issues, the findings are independent and there were few applicable systems designed with integrated interface solutions to really solve actual design communication needs. Most of the research prototypes were not developed within the contexts of real world use scenarios and processes. Commercial tools, on the other hand, have tended to provide more pragmatic functionalities for remote graphic and video/audio sharing yet simply adopted common production-oriented design principles of software graphical user interface. Both the precedent research prototypes and industry applications could not achieve sufficient consistency of dynamically exchanged information and fluency of interaction processes as a result of inappropriate and disintegrated solutions to the four identified factors.

2. Problems

To build a right tool for graphic-centered remote design interaction, our efforts have first been made in understanding the empirical difficulties the existing tools have incurred. In our previous studies, we conclude the incapability of current remote tools for design interaction come from the following:

(1) Support for personal productivity instead of interpersonal communication. The interface design of existing tools is meant to facilitate personal productivity (independent process) rather than to optimize interpersonal communication (participatory process). Software GUI remains mired in the quest for increased personal efficiency and does not reflect the fact that the computer today is predominantly used as a shared platform.

Image browsing without visual contexts in space and time

The most crucial advantages of a collocated design pin-up discussion are its flexibility and ample presentation space. The presenter can lay out drawings on the wall based on intended presentation flow (temporal context), while retaining the articulation of their semantic relationships (spatial context). The enabled visual continuity and context in time and space ensure synchronization of the behavioral and cognitive activities among participants which underlie the transparent experiences of image browsing. Unfortunately, such a clear spatiotemporal contextual map for interactive navigation is not available with digital design communication due to the natural constraint of screen real estate, which allows only a limited number of discernible drawings concurrently.

Rigid presentation layout neglects semantics and presentational relationships among design drawings

The presentation of an architectural design has a unique way of being interpreted compared to that of other visual artifacts. Because of the range of scales and spatial organization in design, a typical set of architectural design drawings may be composed of concept diagrams, site maps, plans, sections, elevations, perspectives, rendered images, animations, and 3D models. Each type of representation interprets certain attributes of a design; therefore, there exist three levels of semantic relationship among architectural drawings, creating complexity in the presentation of three- or multi-dimensional forms: 1) spatial relationship 2) conceptual relationship 3) logistic relationship. In the configuration of a physical presentation environment, these relationships can be comprehensively revealed through conscious manipulation of graphic layouts by the presenter. Graphic strategies including relative location, order, size, contrast, proportion, adjacency, or overlap are commonly deployed to construct a hierarchical organization of drawings in space to establish visual contexts. However, existing software applications tend to standardize or modularize image displays rather than prioritizing or contextualizing them in time (sequence) and space (relation) at the visual level. The thumbnail view, for example, evenly distributes images and therefore leaves few clues for others to visually map the interconnections among them. It lacks the mechanism that would enable flexible graphic arrangement of design drawings and is contextually unresponsive in terms of spatial comprehension through graphic correlation.

(2) Do not support the actual intensity and improvisation of interaction patterns

A design review is based on continuous visual interactions with drawings and dynamic conversation between the presenter and critics. The pattern of such verbal-visual dynamics can be understood as a major or a few sequential (one-way presentation) and a series of interactive (two-way communication) sessions. Existing tools for remote design interaction fail to meet the needs for intense and seamless visual switching between the two modes. For instance, every time the presenter answers a question by pointing to a specific part of another drawing, he or she needs to skim through unrelated images in the pool of thumbnails in order to identify and zoom into the right portion of that image. It usually takes time to map the exact location of an image which the typical thumbnail view lists based on textual (e.g. by created time or alphabetic order), rather than visual contexts. The constant iterative delay in time and visual interruption eventually reduces the fluidity of communication as well as the effectiveness of interaction.

(3) Asynchronicity of remote participants' presentations and shared design representations

The relational spatial information of architectural drawings can be quickly conveyed through the reference of hand pointing, associating, drawing, and defining boundaries or orientations over presented images. However, "our hands' capabilities for expression are only poorly approximated by a telepointer". It lacks the competence of hand gestures in agility of function transition, legibility for focus direction, and visual expressiveness in relation to design representations.

3. Design Criteria

In order to resolve the identified problems, we propose four strategic design criteria and interface design principles to enable dynamic and seamless remote design interaction.

Strategy I: Contextualize

From "desktop" to "walltop": establishing visual and spatial relationships among design representations.

The first design criterion is to transform the metaphorical concept of a personal, task-driven, and content-independent "desktop" workspace into a more interpersonal, coordination-driven, and contextual "walltop" communication workspace. The central idea is to reveal semantic and presentational contexts of drawings in a single view space in order for remote participants to cognitively correlate, differentiate, and categorize them for relational comprehension so that more integral feedback can be given.

Strategy II: Optimize

From "narration" to "improvisation": enabling improvisational interactions by allowing both structural (sequential) and unstructured (interactive) communication patterns.

As the de facto design review session is composed of structured presentation and unstructured interaction, a communication space must facilitate transparent and swift visual transitions between sequential and non-sequential communication patterns. After the presenter responds to a question or request by referring to a drawing not currently on screen (interactive mode), he or she should be able to seamlessly return to the point in the presentation where it was interrupted and continue the intended presentation sequence (sequential mode).

Strategy III: Visualize

From "pointing" to "gesturing": articulating graphical concepts by instant and dimensionally-enhanced visual expression.

Since body language and gestural activity are not visible in the virtual space, a new kind of medium is needed to effectively synchronize verbal and visual presentations. Besides directing the focus of attention over presented drawings using the mouse, there needs to be a more sophisticated way to dynamically indicate spatial (e.g., dimension, area, orientation, etc.) and graphical (e.g., shape) concepts in relation to drawings.

Strategy IV: Spatialize

From "interface" to "space": enhancing social and behavioral contexts by spatializing critical user performances.

There has been a significant shift in the design of the virtual workspace from the notion of an interface aimed at mediating user operations and functions to the notion of space to accommodate user activities by revealing their spatial associations with artifacts and other users to heighten social awareness. An interface helps get things accomplished but a space helps make things comprehensible and communicable. To enhance social awareness by means of spatializating user performances, four critical knowledge about others which will frame interactive behaviors in design communication must be presented in space: (1) personal identity (2) active speaker and turn-taking (3) focus of attention and (4) location and movement of participants.

3. Prototyping Telepinup System

With the established criteria regarding contextual navigation, improvisational patterns, workspace awareness, and a richer synchronizing medium, the objective of the Telepinup System prototype is to propose a series of creative and efficacious solutions in order to achieve the spatiotemporal consistency of a physical design communication space through its usable interface. There are sixteen proposed solutions at the end and the most critical ones are explained as follows categorized by their applied functionalities:

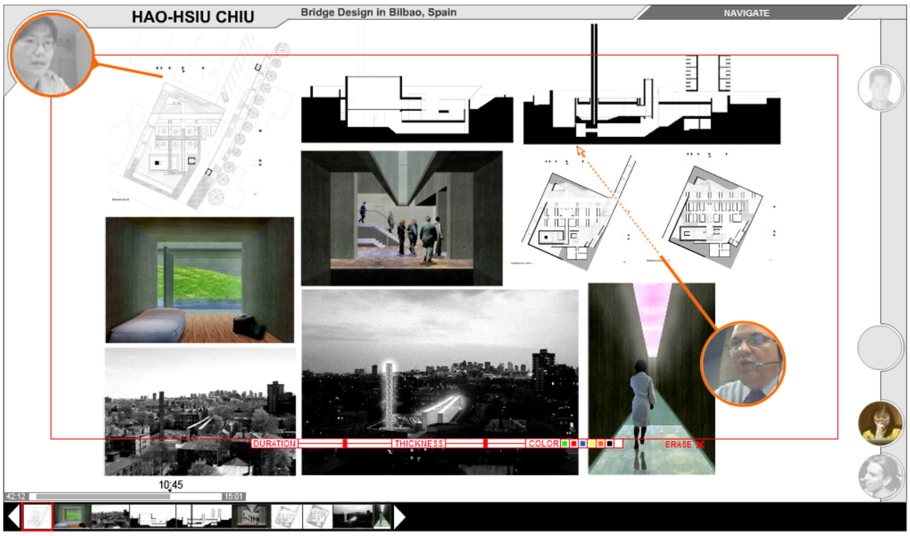


Figure 1. The interface of Telepinup system

To facilitate seamless navigation and improvisational interaction patterns:

Contextual thumbnail map: Instead of the traditional image thumbnail view which allows the user to search for and locate an image depending on his or her familiarity with the content, the contextual thumbnail map is proposed to allows the presenter to freely lay out design drawings in the borderless digital pinup space according to design and presentational intentions.

Spatial navigation and trail tweening: Rather than moving contents around the space independently, space-oriented navigation enables the user to mobilize the entire presentation space (or relatively speaking, the view area) along with contained drawings. When the presenter is refocusing from one drawing to another, all other drawings are still shown and moving in such a way as to maintain their spatial consistency and context. The tweening animation while moving from one drawing to another every time the presenter redirects the visual focus is also shown to allow visual continuity of space and over time their collective trajectory increases spatial memory.

Concurrent independent browsing: Telepinup system also allows any remote participant to temporarily “detach” or “escape” from the shared view and look at other drawings or other parts of a drawing while still following the verbal presentation. Such autonomous navigation capability helps a critic further explore the design contexts without interrupting the main presentation stream.

To enhance workspace awareness:

Video-embedded avatar: Video-embedded avatar is the live remote user representation through video-conferencing web camera presented as a circle in Telepinup space. Logged-in participants will first be listed as circles to the right and re-ordered over time according to their amount of speech during the interaction process. The major presenter appears at the top left corner and active speaker will jump out to the middle of the space as a bigger circle to indicate its active speaking status. Those who are in the "independent browsing mode" will be shown as a grayed-out video image to indicate their temporary "absent" or "off-focus" status. This representation transmits facial expressions while incarnated as a digital avatar with the capabilities to virtually "perform" or "act" in space.

Pointing hand and action cue line: Pointing hand is a novel way of pointing that appears as a rotatable stylus attached to the active circular video avatar with a cursor at the end of its pointing direction. The length of its "stylus" or "hand" is dynamic, reflecting the distance between the circle (avatar) and the cursor (directing focus). This is particularly helpful for participants, on the one hand, to locate the visual focus more easily with additional spatial clues, and, on the other, to be made continuously aware of the identity of the active speaker and his or her actions and intentions. Action cue line appears as a dotted connection line between the pointing hand and cursor at the moment when the represented user clicks somewhere on the screen to trigger an event like selecting an image. So who is doing what, when and where is clear to others on a continuous basis throughout the process.

To enable instant and rich visual expressions:

Temporary scribbling (to approximate gesturing): The active speaker may scribble on the selected drawing using this mode to express spontaneous thoughts. The drawn strokes fade out within one second automatically by default and the fading time is adjustable. The fading out effect allows transitory expressions, which are similar to physical gestures, to visualize quick spatial concepts over drawings without reducing legibility.

4. Evaluation of Telepinup System

To evaluate the effectiveness and usability of Telepinup system, the prototype was tested in two different, real-world, design communication scenarios. Two kinds of information were collected and analyzed from the real use contexts of each test: qualitative empirical data and quantitative interaction data. The qualitative data are comprised of empirical user feedback on individual features and the system as a whole. The information was gathered using direct observation, participant interviews, and questionnaires. The quantitative data measured participant interaction in spatial and temporal contexts, such as switches in visual focus, visual input (e.g. scribbling or drawings), duration of discussions about certain images, and so on. Such information would be used to prove the supported dynamics of use.

Hardware settings

The participants were set up in two separate rooms to ensure visual and acoustic isolation. The participant in Room A was equipped with a laptop computer running the main Telepinup System prototype, a web camera, and a microphone. The software was shared with the participant in Room B using a long SVGA cable to project the same image appearing on the screen in Room A but on a larger scale. The original plan was to use another laptop computer to also run the software in Room B. However, identical desktop sharing (not desktop extension) between two local computer monitors is not supported by Windows OS. Therefore, the external projector was necessary to share the prototype software. Both participants also shared control of the same mouse cursor to operate the software by a USB extension cable and a hub connected to a separate PC mouse and an additional web camera so that video conferencing was also available. Lastly, a laptop computer in Room B was used for the purpose of establishing the audio connection with the computer in Room A through the network using VoIP software (Skype).

Software settings

The only software requirement for using the Telepinup System prototype was to have Macromedia Flash Player 6 (or later versions) installed on the computer. In addition, in order to record user interaction for later analysis, Flash Actionscripts codes were embedded in the prototype to save recorded information to the mySQL database in real-time using PHP scripts on a web server. The dynamically stored data are (1) which drawing is being focused on; (2) when the overall view (contextual thumbnails) is shown; (3) when the focused drawing is being zoomed in (or out) on; (4) when the focused drawing is moved; (5) the location of the participants (video-embedded avatars) in space; (6) when the active speaker is talking; (7) when the active speaker is using the "temporary scribbling" function; (8) when the active speaker is drawing (markups); (9) the length of time a drawing is focused on; and (10) the number of visits to a particular drawing.

User test 1: Remote Desk Crit Scenario in Learning Environment

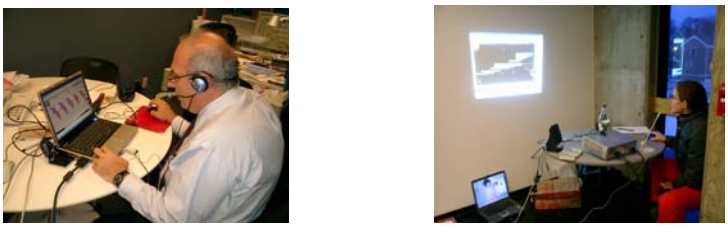


Figure 2. The studio instructor remained in his office (left) using the prepared laptop computer running the software prototype, while the student presented her design from outside the office in a corner of a small, public area (right)

The goal of the first user test was to evaluate the Telepinup System prototype in a design desk crit situation in an educational environment. A student volunteer from an architectural design studio at the Harvard Graduate School of Design participated in the test session to present and discuss her in-progress design with the studio instructor two weeks before the final review. She was asked to put her drawings in the intended presentation sequence so the pinup layout of drawings could be determined by both the presentation sequence and the properties of the drawings. As soon as the physical setting was ready, the instructor and student were given a brief (under two-minute) introduction to the overall interface and navigation techniques, including how to switch between drawings, zoom in and out, move a drawing around, use temporary scribbling and so forth followed by the actual test session. The student began the desk crit with a short presentation of her recent progress and this soon turned into a mutual discussion about design details. Despite having no experience beforehand, both the instructor and the student adapted to the hardware and software mechanisms very quickly and were able to effectively communicate about the presented drawings using Telepinup System. Although it took the student a few attempts before becoming accustomed to the navigation, she felt comfortable using it once she understood how it worked. As she stated in the survey: "…just the simple clicking is very straightforward once I got the hang of it." It appeared that the instructor mastered the technology even more rapidly.

During the interaction process, the student jumped among drawings quite often, not following the planned presentation sequence. The order was evidently improvisational as it was based on the instructor's inquiries or ideas sparked by what was viewed on the screen. "Sometime seeing different images next to each other is a happy accident and gives one ideas" is how the student described this spontaneous interaction. The proposed "contextual thumbnail map" not only helped the student find targeted images efficiently, but, more importantly, encouraged the visual serendipity critical to such an open-ended design discussion and to learning in general.

Interaction data analysis

Another important element of the evaluation was the visualization of the collected interaction data. This information, depicted in Figure 3, was shown to both users immediately after the critique. The X axis (from left to right) indicates the image presentation sequence that the student originally

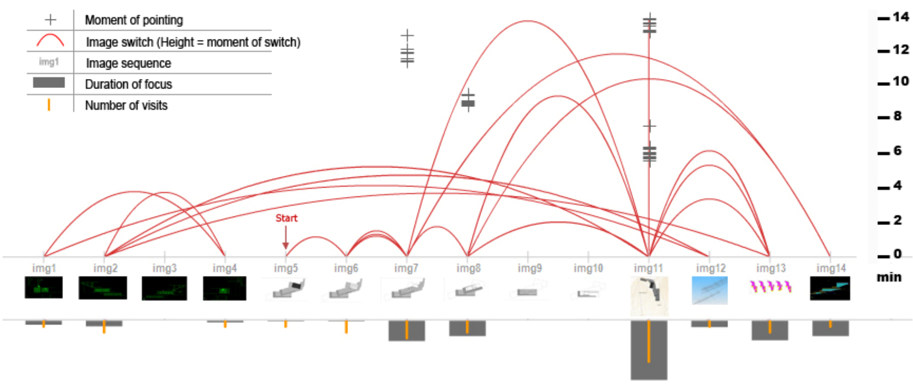


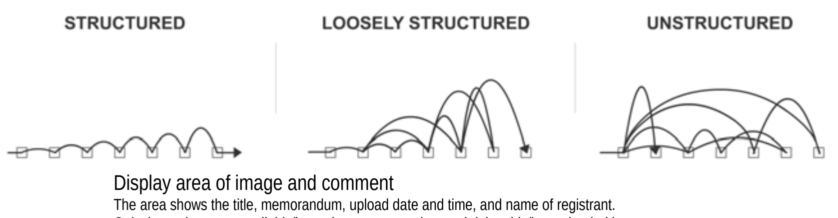
Figure 3. The automatically generated interaction pattern of the simulated remote desk crit

intended to follow. The parabolic curves connecting the image thumbnails represent the focus switches or visual transitions from one image to another which occurred during the interaction process. The peak of each curve marks the time of that specific transition relative to others. The starting point of the desk crit session is indicated on the upper gray line: the higher the highest point of a curve, the later that transition took place.

Consequently, the curve pattern tells us that the student started her presentation at image 5 and then went to image 6 soon after since the arc connecting these two images is not significantly higher. In contrast, the highest curve going from image 7 to image 11 suggests that this focus switch happened at the end of the discussion (while the equally high straight line on image 11 could represent an operational mistake, such as clicking on the same image twice). The black cross symbols on top of images 7, 8, and 11 mark the moments when one of the participants was “gesturing” to convey visual ideas about those drawings using the “temporary scribbling” tool. The orange pen symbol would indicate use of the drawing tool, but it was not activated in this test session. Below the lower gray line are dark gray bars, the length of which represents the relative duration of focus on each particular image. In other words, image 11 was discussed the most as it has the longest bar while images 3, 9, and 10 were not viewed at all since they show no bars beneath them. In addition, the length of the vertical thin lines in the middle of each gray bar shows the number of visits to each image. An image with more visits (a longer thin line) but of shorter duration (shorter gray bar), such as image 6, was presumably used as a quick reference to support associated images, such as image 7, which was discussed at greater length.

Interestingly, the resulting pattern demonstrates the following facts:

(1) The pattern of the design interaction was loosely structured rather than completely structured or unstructured. Based on the visualization, we might easily conclude that the enabled interaction pattern is completely improvisational or even random given the constant switches among drawings. Yet there is actually an observable sequence that the student tried to maintain. She started with a set of architectural plans (images 5 to 11), then went through a series of elevations (images 1 to 4) and finally discussed other drawings. However, while she was following this general course, either she or the instructor repeatedly veered from the plan and referred to other, related drawings. Therefore, the pattern could be considered a loosely structured linear presentation as shown in the middle of the diagrams below (Figure 4).



(2) The visualization helps optimize the results of design review for participants. When the visualization was shown to the student, she found it a great resource for planning the order of her presentation and pinup layout for the final review. The pattern depicts the relative importance of each drawing and the connection among them as manifested by the critic’s focus of attention in a temporal sense. Such information can help a participant not only trace back significant discussions about certain drawings but also improve the next presentation or even the design itself by rethinking the graphical contexts.

User test 2: Remote Design Collaboration Scenario in Professional Practice

In the second user test, the Telepinup System prototype was used to support design discussions about a real-world project. Two urban designers from a multidisciplinary design firm that provides international consulting and design services in architecture, landscape, and urban planning, were asked to participate in the evaluation process. The entire interaction lasted twice as long as the previous test since it examined every critical aspect of this large-scale and complex project. As in the previous evaluation, the participants frequently jumped around among drawings but still generally followed their presentation plan. Throughout the process, both participants took advantage of the temporary scribbling tool which allowed them to continuously "gesture" visual ideas over drawings without having to delete previously drawn graphics. At the end, both participants felt that the prototype's ability to support open-ended and dynamic design discussions exceeded their expectations. They appreciated how easily and quickly they could relate and access drawings with the enabled contextual and continuous visual accessibility. In general, they saw the great potential of the tool to be deployed in a variety of professional situations. On the other hand, the visualization from the collected activity logs also illustrates a similar combination of structured sequence and unstructured improvisation in the end.

In spite of the relative similarity of the interaction patterns, the two designers emphasized several distinct requirements of professional design discussions that are not necessarily applicable to educational environments: (1) The enabled dynamic and open-ended pattern of interaction may not be appropriate for presenting ideas to clients who are relatively unfamiliar with the design. Constantly jumping back and forth among drawings may be confusing to clients, for whom a more organized and consistent presentation is preferable. (2) Additional features may be needed to meet professional design communication requirements such as markup tracking, real-time measurement of scale and dimensions, and on-demand visual change of material or pattern representation. These features are considered important and can be easily added but beyond the scope of the research.

5. Conclusion

The user feedback on the prototype of Telepinup System for professional design collaboration was encouraging. The participants recognized its potential for being used in diverse practical design discussions among remote team members, consultants, and subcontractors. With similar positive feedback on its intuitive navigation, flexible graphical communication pattern, and instant, rich expressive capability, the participants stressed that its usefulness came primarily from its ability to enable an extremely dynamic and open-ended interaction style for internal design discussions. The latter attribute is also the most compelling feature distinguishing the Telepinup System from existing remote presentation or collaboration tools that support only rigid image-sharing processes.

The participants' empirical responses and the visualizations of the interaction patterns derived from the user tests provide positive evidences toward a seamless virtual space to: (1) allow relational graphic presentation and intuitive navigation (2) allow both structured and unstructured communication patterns (3) enable instant and rich visual expressive capability and (4) enhance workspace awareness in spatial contexts. Except for the fact that some group awareness features could not be evaluated due to the one-on-one test setting, most of the prototype's solutions proved effective in achieving the first three objectives. This implies the prototype should be further evaluated at a larger scale of user participation for future research.

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