# MAGIC BOARDS

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## ABSTRACT

Graphically augmented video replaces live elements with computer graphic imagery. Graphical augmentation is useful for video recordings of chalk- and marker-board sessions, as it can enhance legibility, comprehensibility, and improve visual interest. Unfortunately, creating augmented video requires laborious post-processing unless the source video is specially structured. This precludes its use for board capture applications. In this paper, we present *Magic Boards*, a post-processing system that facilitates the creation of augmented video of board sessions. The system automatically determines a structure of source video, allowing live visual elements to be replaced easily. Tools enable an author to replace regions of board writing with images and video. The results allow standard captures of board sessions to be transformed into augmented video with minimal effort.

## 1. INTRODUCTION

Augmenting video by replacing real elements with computer graphics can add clarity and visual interest to presentations. To create such augmented video, the live elements must be identified and replaced in each video frame in a way that they integrate with the presenter's actions and timing. This requires either a laborious process of per-frame editing, or careful pre-planning such that the initial video has structure to facilitate augmentation. Our overall goal is to enable augmented video in situations that preclude such planning. In this paper, we introduce *Magic Boards* a system for producing augmented video of marker- or chalk-board sessions where neither careful pre-planning nor laborious post-processing is feasible.

There are several reasons for wanting to use a chalk- or marker-board. The board is a tool that gives the presenter a level of freedom and spontaneity that is not available with a pre-planed presentation. Using a board, the presentation can be adjusted to the individual needs of the audience; e.g. answering questions or spending more or less time on a specific topic. A board is also useful in situations that a pre-planned presentation does not make sense, such as a collaborative discussions, brainstorming, problem solving.

Video recording such interactions is useful for archival and later review. However, the resolution and placement of camera, sloppy handwriting and other limiting factors may make the board difficult to read. This makes board capture an ideal candidate for augmentation. Magic Boards makes easy board augmentation a reality.

The key insight of our system is that by finding a structure in the video, namely by identifying and grouping writing on the board into *regions*greatly simplifies the augmentation process. An author, someone who is familiar with the board session, is presented with a single image representing the writing in each region. The author will repaint or replace each region. The system will replace the writing with the new information. Figure 1 shows the flowchart of the Magic Boards system.

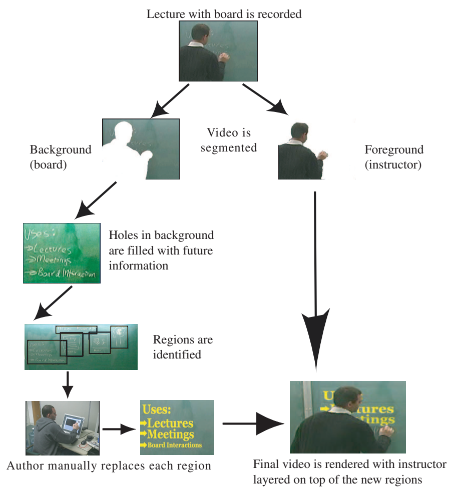


**Fig. 1**. Flow chart of processing steps for Magic Boards.

## 2. RELATED WORK

Our goal is to be able to get the benefits of spontaneity and collaboration that are afforded using a marker or chalkboard,

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but be able to augment the board with high detailed pictures and videos. In the final video, the board contains special effects similar to those in a well planned computer presentation. For example, a handwritten list may be replaced with a type written bullet list, or a simple drawing may be replaced with an animation. In this section we will discuss some related efforts and systems. Other work in this area has either focused on improving low resolution of the board capture, or editing general videos. No other work that we are aware of looks at directly editing a chalk or marker board.

Dealing with low resolution of a board may be handled by a system or tool which increases the resolution of the board capture. This can include a marker board scanner [1], an electronic marker board [2, 3], or a photography-based board capture solution [4]. These devices use special hardware to digitally capture the writing. This writing can then be displayed at a higher resolution than video alone.

While board capture devices offer a solution to low resolution, they do nothing to make the writing more detailed or correct sloppy handwriting. Video editing solutions such as Adobe After Effects, or Proscenium [5] can be used to replace the writing on the board. However, using such editing tools is inefficient as they are designed to do general purpose video editing. Magic Boards requires that the author repaint each piece of writing on the board exactly one time. This writing is found automatically for the author, so searching through the video for the writing is not necessary.

## 3. REGIONS

In order for an approach such as Magic Boards to be useful, we need to minimize the amount of required manual work. Repainting every single frame is generally too labor intensive to be useful. To simplify the process, we group related writing together such that each grouping only needs to be replaced once. We call each grouping a *region*. The idea of a region was first presented by Gleicher et al. [6] as a partitioning of the board into related groups of writing.

Each region represents a single thought or idea that is written on the board. Current technology does not provide a way to automatically extract this semantic information from a video. We developed a technique for estimating the bounds of the regions based on heuristics of writing, through time. Each region passes through a specific lifespan. The region is said to be born when the first stroke of writing for that region is written on the board. A region is mature when the last stroke of writing is added. Finally a region dies when it is erased or the lecture ends.

A full technical description of our region finding technique can be found in [7]. Briefly, we look for changes in the board over time. Small changes that occur over a small amount of time are grouped together as a single region. An example of the region finding algorithm is shown in Figure 2.

In order to find the regions, our program must create a

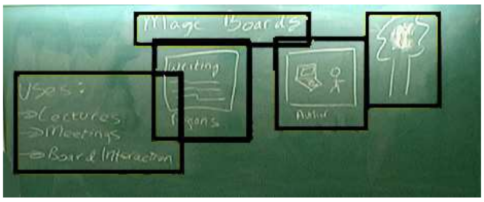


**Fig. 2**. Example of the region finding output. Each found region is marked by a black box.

clean stream of the board (i.e. remove obstructions). This artifact is useful as it presents an approximation of what writing was on the board at any time. The system makes use of this stream when creating the final video. The clean stream video is created by using color classification [8]. Pixels that not board colored are replaced with a board colored pixel from the same spatial location from a different frame.

## 4. REPAINTING THE REGIONS

An author is presented with a single image representing each region. Images are taken from the clean stream of video between the regions maturity and death. It is the author's job to replace each region if desired, and determine when parts of the replacement image will be phased into the final video.

### 4.1. Replacing Regions

It is the author's job to create the replacement regions, and decide when to phase in parts of the new region. The author may use other information about the event in order to understand what was written on the board, and chose appropriate media for the new regions. The level of detail that goes into the new regions is completely at the discretion of the author. For example, the author may choose to simply trace over all of the drawn lines to make them more pronounced, or replace the drawing with a digital image or video.

The author must provide the system with new images or videos for each region. For the examples in this paper we used Adobe Photoshop and a Wacom tablet to draw new images. However, any means of acquiring new images can be used. We have found that when repainting the regions it is helpful to increase the scale of the region images to make the painting easier. This also creates a high resolution artifact that may be useful for other purposes.

When replacing the region with a video we provide several controls the author when the replacement video lasts a different amount of time than the region's lifespan. The author may choose to have the video loop until the region dies, stop on the last frame when the video ends, or specify a linear time warp. Using the time warp, the author can ensure the key points of the replacement video will synchronize with the presentation.

When replacing regions with video the author must also be aware of the aspect ratio of the video relative to the size and shape of the region. Magic Boards will resize the region to match the aspect ratio of the video, however, it would be unwise to put a video with a $4 \times 3$ aspect ratio into a tall but narrow region, as this may not look visually pleasing in the final result.

### 4.2. Exposing the Repainted Regions

When a region is replaced with a picture, the author may not wish to expose the entire image at once. In this case, the new image can be exposed in sections. For example, if the presenter is drawing a list, the author may wish to expose each element of the list as it is written. In the simplest case, the author may choose to expose the entire new region at once.

Both the original video and new region image are displayed to the author who marks parts of the image to expose at the current time index of the video. The parts to expose are internally represented as a set of alpha masks, one for each entry that the author specifies. The author may move through the lifespan of the region to mark exposures either frame-by-frame, playing the video, or as each stroke of writing appears in the clean stream. If the region is replaced with a video, the author specifies when to start the video and time warping.

### 4.3. Rendering the Final Video

Once the regions have been repainted, and exposure times specified, the new video can be rendered. We resize the replacement regions back to the size of the original region and composite the new regions into the video. In the case of videos, we reduce the size of the region in one dimension to respect the aspect ratio of video being inserted. We do not increase the size of the region, as this may cover up other regions. For each frame in the original video the new regions are composited into the frame, as specified by the author in the previous subsection. Additionally, we add a dissolve component when compositing the still image regions into the original frame. This gives a less jarring feeling.

In order to prevent the new regions from blocking the presenters or appear to be floating above the board, the clean stream video that was created by finding the regions is used. For each frame, pixels that are marked as "non-board" replace any pixels that represent the new regions. An example of the presenter layered above a region is shown in Figure 3.

## 5. MAGIC BOARDS VIEWER

The videos created using Magic Boards are standard AVI (Audio Visual Interface) files, and may be played back in any standard viewer. To increase the viewing experience, we built a new viewer program which takes advantage of the concepts presented in Magic Boards. Figure 4 shows a screen capture of the Magic Boards Viewer.

**Fig. 3**. The presenter is partially obscuring the new region. The presenter remains above the new image.

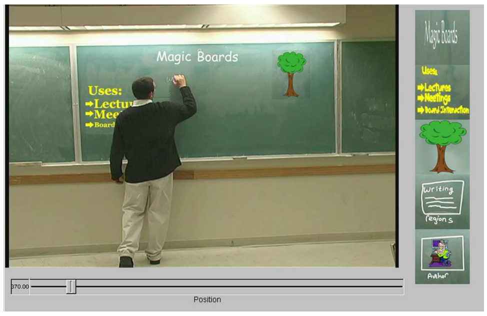


**Fig. 4**. Magic Boards Viewer program, which takes advantage of meta-data when playing back the video.

The Magic Boards viewer uses meta-data associated with each video and region to enhance the viewing experience. First, each repainted region is shown to the right of the video as a thumbnail image. Clicking on the thumbnail causes the video to go to the birth of the region; double clicking advances to the region's maturity. It is possible for the author to add more meta-data for the viewer program to use. For example, in our current implementation, we allow the author to add an external pointer to each region. Clicking a region inside the video spawns the external pointer, such as a program, web page, supporting document, etc.

## 6. EXAMPLES

We have used Magic Boards to enhance videos of several different board interactions. Our examples were all in a classroom domain, in both scripted and spontaneous lectures. It should not be difficult to image using Magic Boards in scenarios that extend beyond classrooms. The following are examples of the different chalkboards after they have been processed with Magic Boards. Example videos may be found on our web site at: http://www.cs.wisc.edu/graphics/Video/

## 7. CONCLUSION

In this paper we presented *Magic Boards*, a system for augmenting the marker or chalkboard in a video. The system can


**Fig. 5**. Writing on the board is replaced with type written text, still images and video.


**Fig. 6**. Writing is replaced with type written text.

be used in any situation that uses a board, such as a classroom lecture or meeting. The writing on the board is replaced with new images or videos and animations.

Magic Boards works by using the regions concept. Each region is the writing of a single thought or idea written down on the board. By requiring the author to only regions, we minimize the amount of work required to create new videos.

The author repaints each region using high resolution photographs, type written text, videos or animations. The author may also specify additional meta-data, such as an external pointer, that may be used by the Magic Boards Viewer.

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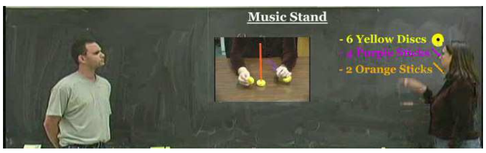


**Fig. 7**. Writing is replaced with type written text, and a video illustrating what the instructors are describing.

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