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6.111 Final Project
Project Proposal

For our final project, we propose to build a juggling simulator. The simulator will take input from a video camera to locate the juggler's hands and display virtual balls on a screen. More specifically, the simulator will consist of four components: a controller, a video processor, a ball manager, and an output module

The most autonomous part of the system will be the controller. The controller module will handle parameter delegation to the various components of the system and clock synchronization. The controller takes in ball increment and decrement signals through buttons on the labkit as well as gravity through switches. Each of these signals will be debounced and synchronized to the frame clock before being passed on to the other modules in the system. There will also be a global reset signal. Within the controller are a number of clock dividers to provide the appropriate clock signals because the processor, manager, frame and display all need to run at different clock rates.

The second component, the video processor, will parse incoming images to determine the location and velocity of the juggler's hands, likely using special gloves to differentiate them from the rest of the image. The position will be calculated by locating the two hands and finding the center of mass for each, from which the velocity will be found using the first difference. The video processor will then convert this information to logical motions, such as "throw" and "catch," that will be sent to the ball manager along with the position and velocity data. In addition, it may send the raw camera image to the output module to store in ZBT memory for display if feasible, otherwise we use a different background and just display the hands.

The third and most central element of the system is the ball manager. This module takes the hand information from the video processor and determines the location and velocity of all the balls on the screen using a physics module. In order to provide n-ball generality, ball information will be stored in a BRAM and the ball manager will sequentially process each ball during every frame cycle. This processing will include reading location and velocity from the BRAM, calculating their new values, and storing them back into the BRAM. The ball manager will also determine whether to catch balls in the air based on their position as well as the hand's state and position. It will also determine whether to throw balls from the hands based on the hand's state, giving each released ball the velocity and position of the hand at that time. The ball's state (in left or right hand, caught or passing) will also be stored in the BRAM. The physics of the system will be determined by a physics sub module that will have a dynamically modifiable gravity given by the user and supplied through the controller. The changeable gravity will be useful for debugging the system at slow speeds and also allow for the user to stand different distances from the camera since the ball position will be updated by pixel location and the further away from the camera the user is, the fewer pixels his hands will be moving. This functionality is useful since gravity needs to be slowed down as the user moves further away to keep the juggling experience constant. The display within the ball manager will output display positions for each ball in the air for each frame and store it in the 2nd ZBT memory. The number of balls in the system can be changed by the user through button inputs given to the controller. The ball manager determines which hand

to put the ball in and then the normal operation of the throwing and catching within the ball manager takes over.

The final module of the design is the output module. This takes the camera image stored in the ZBT memory (if feasible) and combines it with the buffered ball image generated by the ball manager. Finally, the image is sent to an analog XVGA output as the final product of the simulation.

Ultimately, this system should permit a person to realistically juggle an arbitrary number of balls and to dynamically add and remove balls from the pattern. The balls and hands will be displayed on the screen and, if possible, will be displayed over the camera image. If time permits, this would be extended to a two-player version in which the controller modules of two implementations communicate to allow pass-juggling. This will be implemented by modifying the video processor, ball manager, and controller modules. First, another hand signal will be added to the video processor's repertoire. Second, the ball manager will be modified to remove a ball from the pattern and pass its information to the controller upon reception of this signal. Finally, the controller will send the ball information to the controller module of another labkit, which will receive the ball and add it to the pattern using the same signals that are used for the button inputs.

Our current plan is for David to implement the large ball manager module and for Chris to build the other components that surround it. The easiest modules to test will be the controller and ball manager, as they can be tested in simulation. We will attempt to demonstrate entirely correct functionality of these components in simulation before integrating them into the system. The first module to implement in hardware will be the output module, as this will provide one of the primary means of testing the system. This component will be tested by generating a dummy module to provide image data to the ZBT memory that can be displayed on the screen. The second module to be implemented in hardware will be the video processor (with the controller for timing purposes) which will process camera images and pass them on to the output module for display. At least for debugging, these images will be marked where the juggler's hands are detected. At this stage, it will be critical to demonstrate that the video processing hardware produces the correct position and velocity measurements. Finally, the simulation-tested ball manager will be inserted into the system and we will attempt to test the entire simulator, first with one ball in one hand and subsequently with multiple balls and gravitational modifications. Finally, if time permits, the necessary modifications will be made to accommodate pass juggling, which will be implemented and tested in the same fashion as the rest of the system.

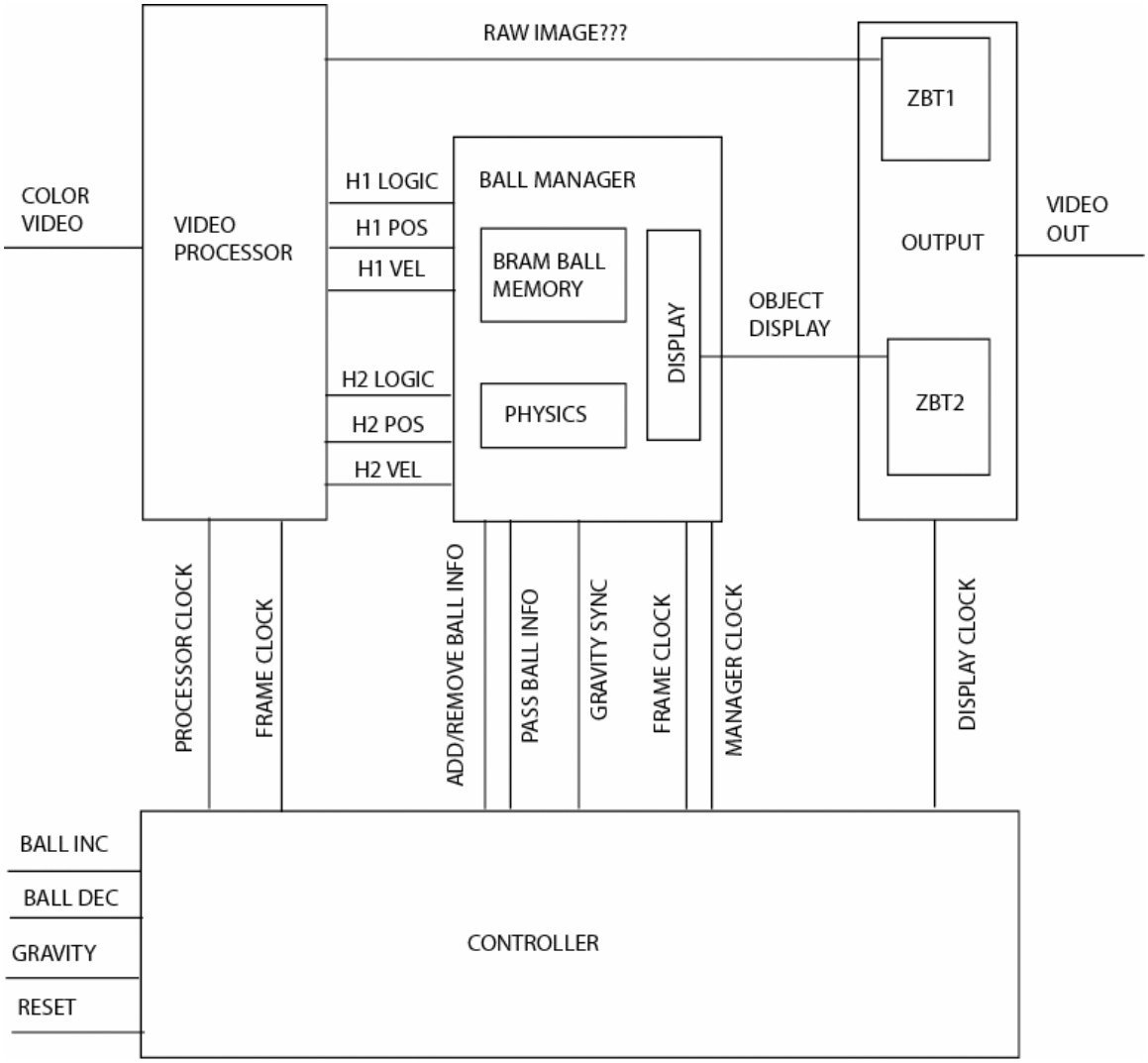

Figure 1: System Block Diagram