Senior Project, Spring 2017

Multi-touch-midair-and Motion for Virtual and Augmented Reality (TAM) Version 6.0

Learning Data Structures with Augmented Reality for Computer Science Education (K-12)

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Problem

Computer Science Education, while based on Mathematics and Philosophy, does not have to be purely axiomatic and abstract. Indeed some our most formative experiences as students and developers come from solving difficult coding assignments or diving into the unknown by adopting new, often poorly supported, development platforms and programming languages. Can learning Data Structures, using the Empirical Model as inspiration, aid in retaining key concepts fundamental to our core curriculum as CS students?

Solution

Vuforia was used on the back-end as the image processing and fiducial marker generator. Using their cloud-server technology we uploaded any image we wanted to their servers, and they would take care of the image-recognition and machine-language training by generating a device image database and a cloud target database to integrate with Unity. Once we had that, we created textures and animations to rig to the specific marker. Then using the animations we created Scenes in Unity, as well as the UI experience that modeled the desired interaction.

Requirements

While we are part of the TAM group, our subgroup was tasked with creating an interactive Augmented Reality (AR) application that displays data structure visualizations in real-time based on interchangeable fiducial markers. While image-recognition (via machine learning) was outside our project's scope, we used Vuforia to create customizable and distinguishable ready-made markers to direct our data structure visualizations. Our project was version 0, so we had to start from the very beginning, i.e. we had to choose our tools, languages, and platforms.

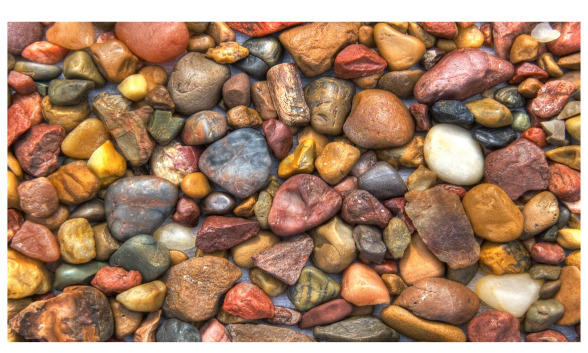


Figure 1: Sample AR marker; it could be anything the user wants it to be as long as the image is high resolution.

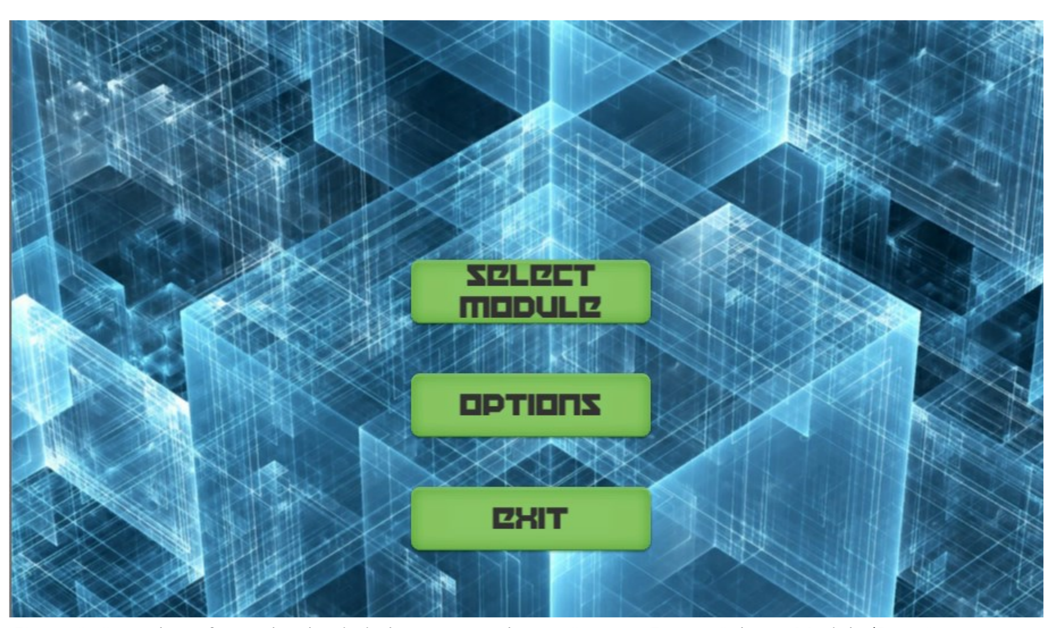


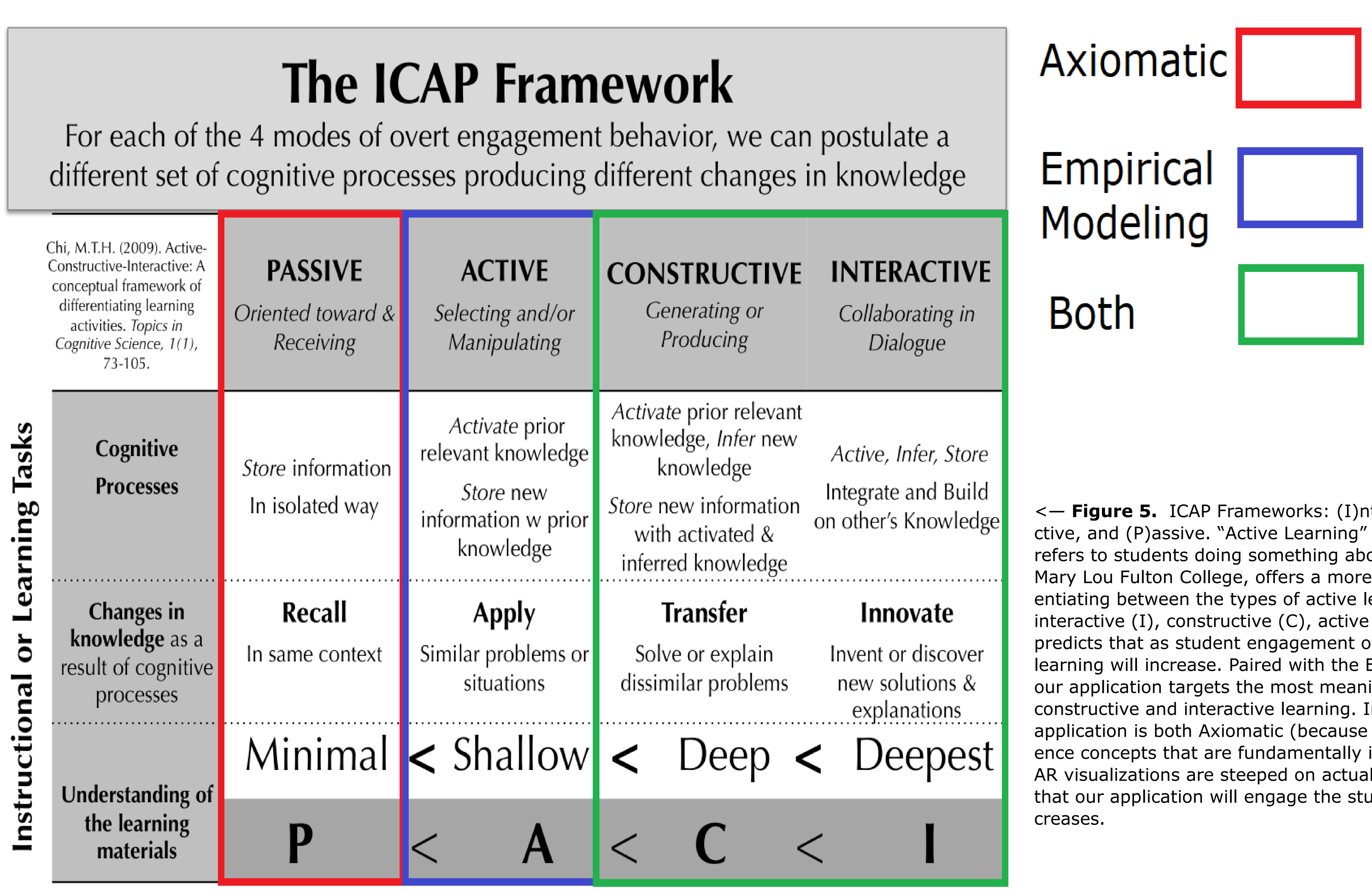
Figure 2: Once the software has loaded, the user can change Options, Exit, or Select a Module (Data Structure Visualization) to display.

Figure 3: A list of available modules populates (due to time constraints we only did an 'Arrays' Data Structure Visualization.

Figure 4: Once the module has been selected an AR visualization manifests.

Research

Our research is based on the Empirical Modeling, which is a conceptual framework for computing based on principles and tools for making construals. Construals are interactive digital artefacts that embody configurations of observables, dependencies and agencies encountered in the situations to which they refer to; within the context of Computer Science education, construals describe emergent properties of axiomatic concepts. For example, a student can know the rules of Sudoku, but until they play it a couple of times—the concept will remain unfamiliar and purely abstract. In the Sudoku game, the construal is the rows, columns, and subdivided squares on the paper representing the culmination of the games' rules. In our application, the construal is the AR visualization representing the concept of an array data structure.



The ICAP Framework

For each of the 4 modes of overt engagement behavior, we can postulate a different set of cognitive processes producing different changes in knowledge

Chi, M.T.H. (2009). Active-Constructive-Interactive: A conceptual framework of differentiating learning activities. *Topics in Cognitive Science, 1*(1), 73-105.	PASSIVE *Oriented toward & Receiving*	ACTIVE *Selecting and/or Manipulating*	CONSTRUCTIVE *Generating or Producing*	INTERACTIVE *Collaborating in Dialogue*
Cognitive Processes	*Store* information In isolated way	*Activate* prior relevant knowledge *Store* new information w prior knowledge	*Activate* prior relevant knowledge, *Infer* new knowledge *Store* new information with activated & inferred knowledge	*Active, Infer, Store* Integrate and Build on other's Knowledge
Changes in knowledge as a result of cognitive processes	**Recall** In same context	**Apply** Similar problems or situations	**Transfer** Solve or explain dissimilar problems	**Innovate** Invent or discover new solutions & explanations
	Minimal	< Shallow	< Deep	< Deepest
Understanding of the learning materials	P	< A	< C	< I

Instructional or Learning Tasks

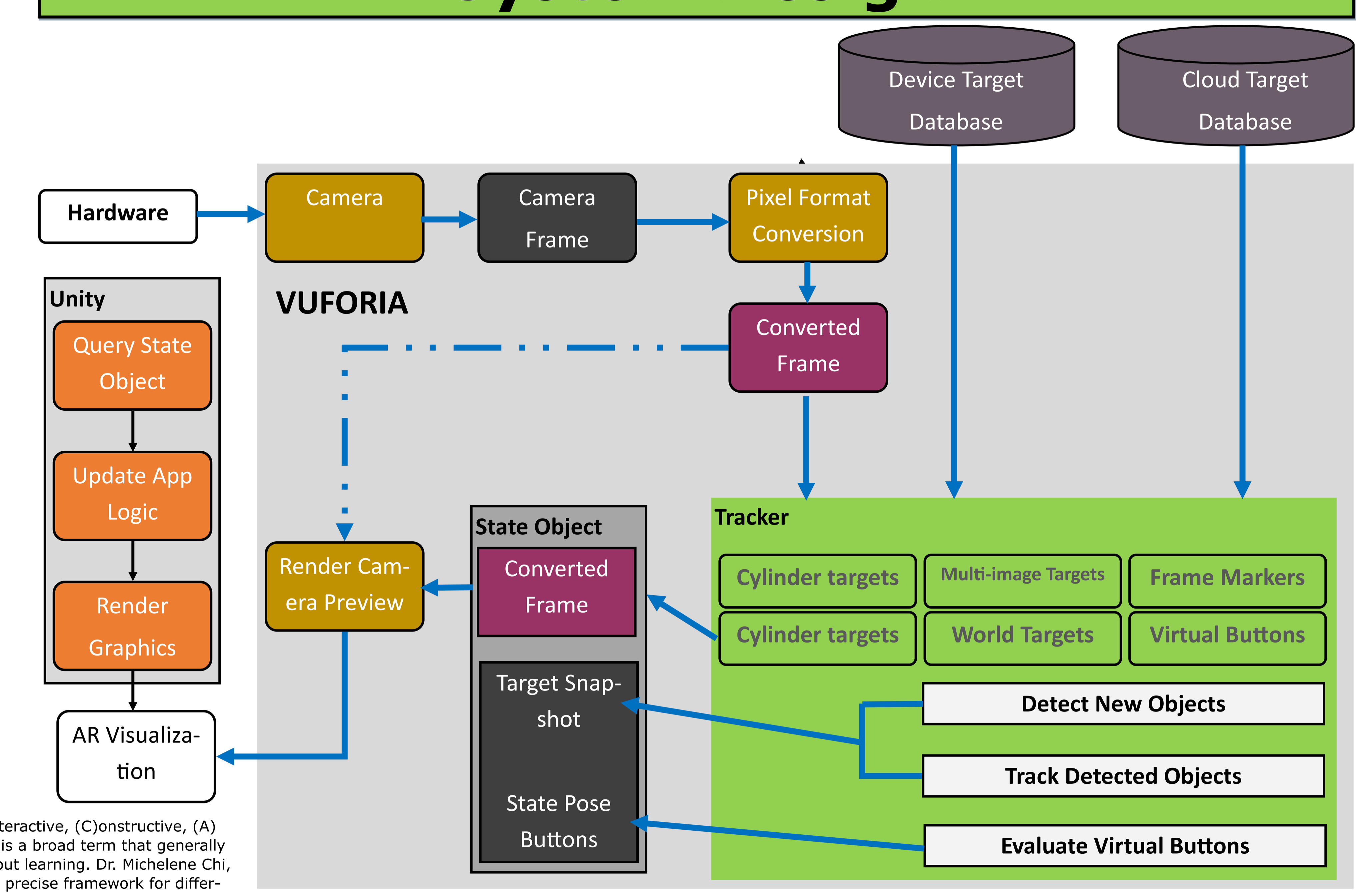
Axiomatic

Empirical Modeling

Both

<— **Figure 5.** ICAP Frameworks: (I)nteractive, (C)onstructive, (A)ctive, and (P)assive. "Active Learning" is a broad term that generally refers to students doing something about learning. Dr. Michelene Chi, Mary Lou Fulton College, offers a more precise framework for differentiating between the types of active learning learners use—interactive (I), constructive (C), active (A), and passive (P). ICAP predicts that as student engagement of learning materials increases, learning will increase. Paired with the Empirical Model, we argue that our application targets the most meaningful kinds of learning: the constructive and interactive learning. In this sense we argue that our application is both Axiomatic (because it's based on Computer Science concepts that are fundamentally inseparable) and Empirical (the AR visualizations are steeped on actual data structure example) so that our application will engage the students so that their learning increases.

System Design



Implementation

The application was built using the Unity Game Engine with the Vuforia AR plugin. Unity is cross platform, allows for the creation of textured models, scripts that target model behavior, and the User Experience. Vuforia was used for realizing AR marker image recognition, machine learning, and AR animations. The application will then be deployed to a Windows-based platform with a front or rear-facing camera.

Verification

In order to validate our application's features we used Unity Test Tools to cover assertions, integration, and unit testing. Agile already lends itself to the development of test-driven features, since a feature-complete Sprint results in a deployable (meaning tested) feature. Using Vuforia also made testing simpler because we did not have to test the image recognition capabilities of the packet, nor every augmented reality marker incorporated into the Image Target Database. We only had to test scene transitions (in Unity) and UI elements such as buttons, scrolling lists, etc.

Object Design

We used the component approach to model our Object-Oriented Programming, which consists of separating the functionality into individual components that are mostly independent of one another. The traditional object hierarchy is dispensed with, and an object is now created as an aggregation (a collection) of independent components (within the context of our application, assets, scripts, and rigs are said components). Each object now only has the functionality that it needs. Any distinct new functionality is implemented by adding a component, each game entity is comprised of a collection of components; the components themselves can be treated as being independent of the objects they make up.

Summary

Learning Data Structures with Augmented Reality for Computer Science Education (K – 12), attempts to assist educators in providing better tools that foster a more comprehensive and efficient education-environment to reinforce learning outcomes. Our tool can not only decrease time needed to create illustrations on white boards by hand, but also presents data structures information in a novel, exciting, and interactive way to make learning fun. This promotes learning by increasing student motivation and attention, which are often difficult to do when dealing with Computer Science learning topics (which often are complex and abstract and, to the student, seem irrelevant).

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