Scenic VR

Developing An Intelligent Tutoring System (ITS) to Train Psychomotor Skills in Virtual Reality

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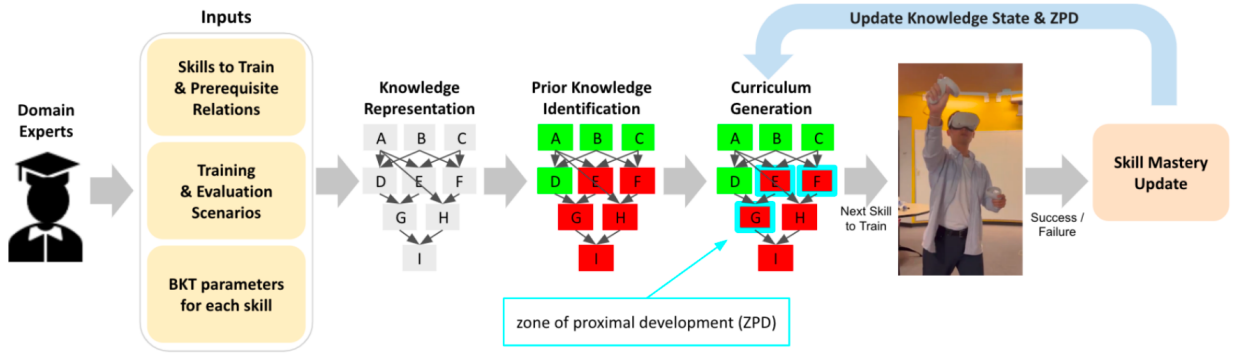

Figure 1: An overview of our proposed intelligent tutoring system architecture for training psychomotor skills in virtual reality

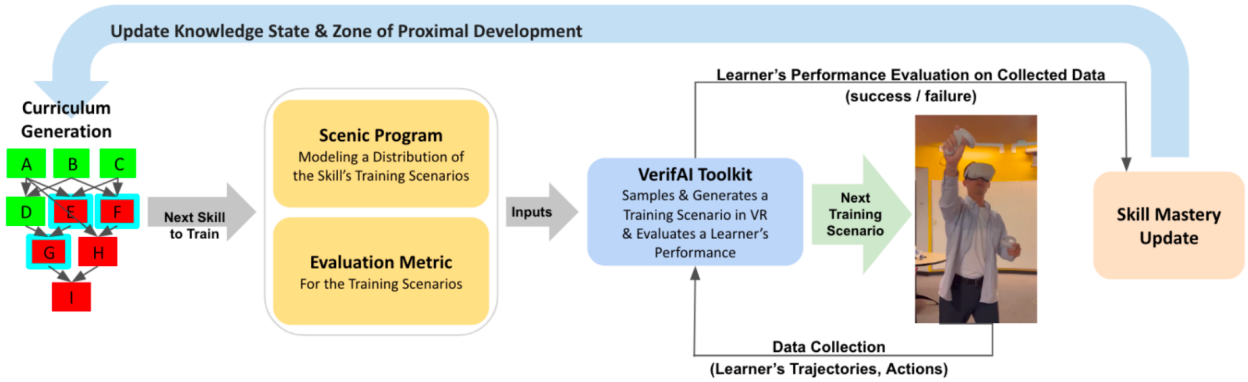

Figure 2: This figure expands the curriculum generation aspect visualized in Fig. 1. Once we select which next skill to train for, we input a SCENIC program modeling a distribution of training scenarios for the skill and its evaluation metric to VERIFAI toolkit. Then, VERIFAI samples a training scenario from the program, generates it in the learner's VR headset, and assesses the learner's performance using the given metric. This assessment is used to update the skill's BKT model.

Context

Intelligent tutoring systems (ITS) have proven successful in academic settings to personalize education to students' varying learning speeds and background knowledge especially when students have limited access to instructors. Similar issues arise when learning psychomotor skills, which consist of spatial perception, cognitive planning, and physical execution of the desired plan via coordination of multiple body joints. Therefore, ITS can potentially be helpful in this setting as well. However, ITS are traditionally designed for purely cognitive skills without any physical motor skills. Most of the literature on ITS for psychomotor skills do not elucidate why certain components of ITS architecture are relevant to these skills requiring motor skills.

Objective

We propose to design our ITS in a way that takes slip rate as a configuration parameter explicitly. Our VR application domain is a popular multiplayer frisbee game, Echo Arena. The skill characteristics for the game is dynamic, interactive, teamwork and real-time

Technical Details: 4 steps

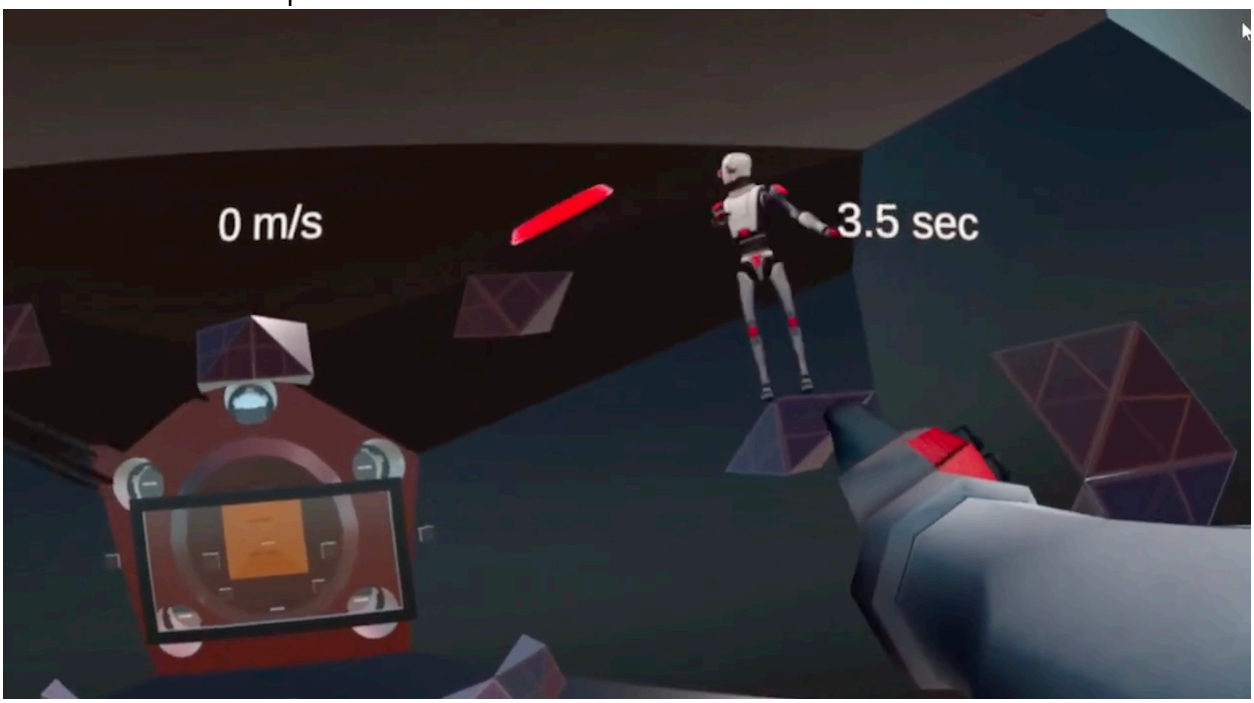

Figure 3: Modeling and Generating Training and Evaluation Scenarios in VR using Unity 3D, this screenshot shows what the trainee will see during one of the training scenarios, which is passing the disc accurately to the teammate.

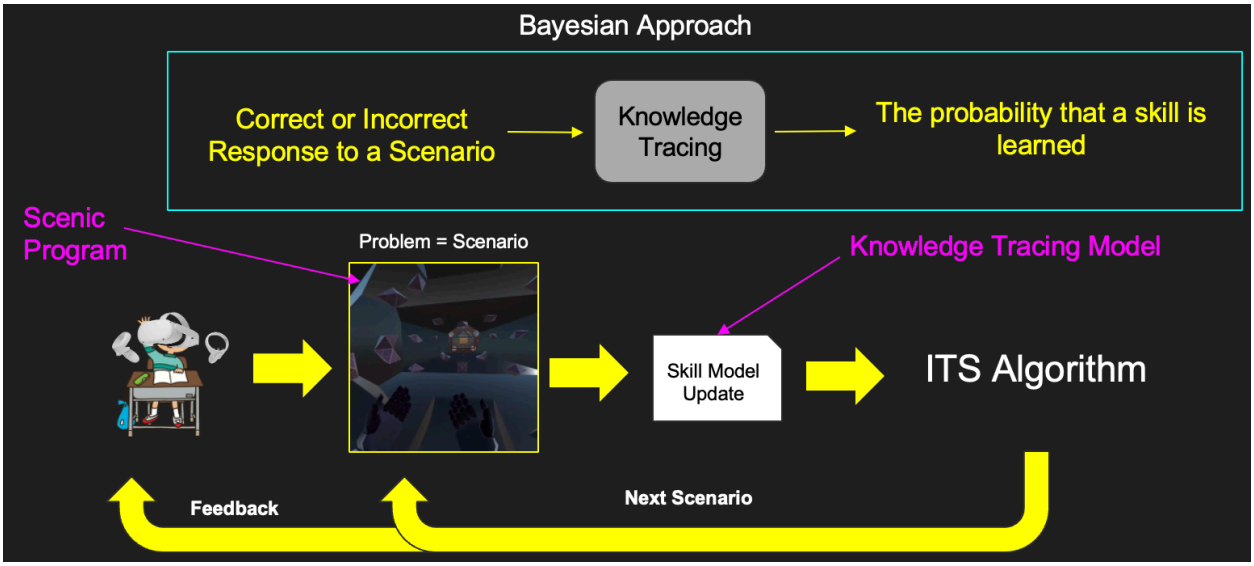

Figure 4: Bayesian Knowledge Tracing (BKT) working scheme, used for estimating student mastery of a single skill

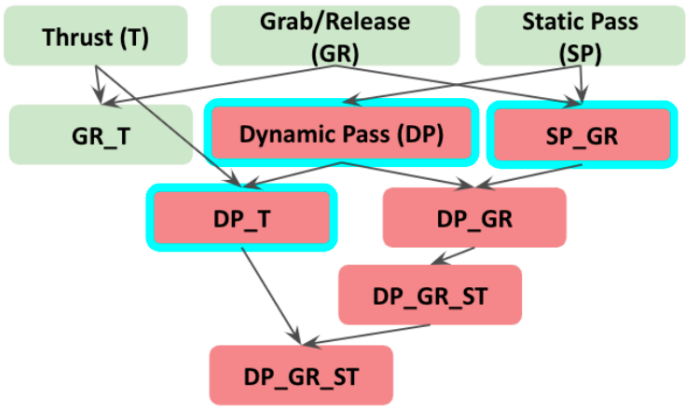

Figure 5: We represent a knowledge state as a colored, acyclic, directed, pre-order graph as visualized in this figure. Each node represents a skill. The directed edges encode prerequisite relations. The color represents mastery (green: mastered, red: not mastered). The zone of proximal development (ZPD) highlighted in light blue is a set of not mastered skills that are in proximity to mastered ones.

Outcome

To address the efficacy of our ITS, we conducted between subjects study and compared to a control condition based on self-guided learning. Our results show that our ITS had 32.3% higher learning gains than the self-guided baseline (p-value < .05) with an effect size of 0.41.

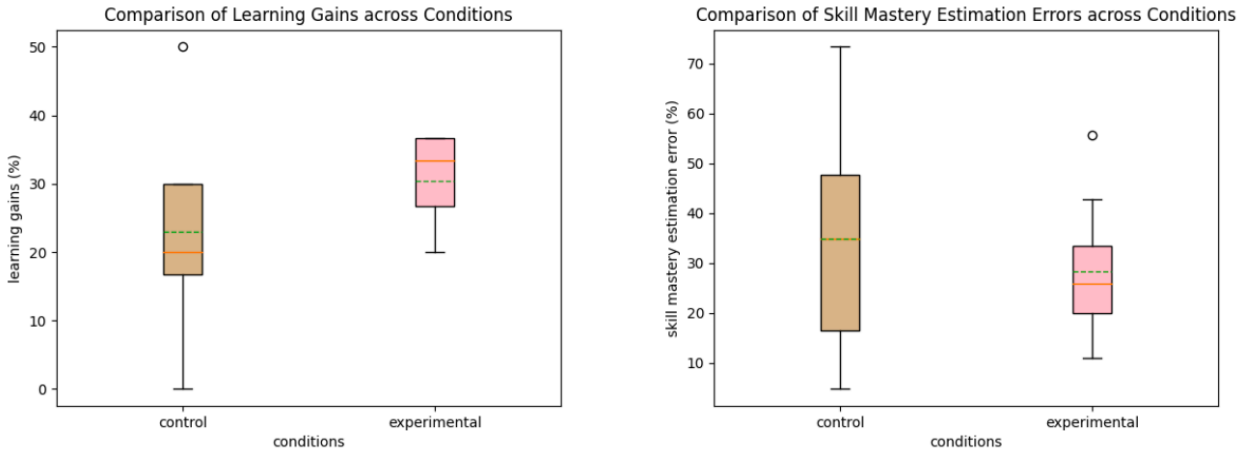

Figure 6: The left box plot shows that the experimental group had higher learning gains in comparison to the self-guided control group. The right box plot shows that the bayesian knowledge tracing models have lower error in estimating skill mastery when compared to learners' self-assessment in the control group. The green dotted line in the box plot represents the average and the orange line, the median.

My Contribution

1. To represent knowledge dependencies, I developed a Knowledge Identification algorithm based on a directed acyclic graph data structure. The algorithm recursively traversed the graph and output the next evaluation scenario with minimal steps for identifying trainees' prior knowledge.
2. In order to evaluate the trainee's skill mastery, I wrote Python scripts to monitor the trainee's physical behavior in VR and provide feedback prompts.
3. I also created a pyBKT package interface to fit the Bayesian model prior to the human experiment
4. I co-developed the VR animation on a Unity 3D engine.