Automated Performance Monitoring

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ABSTRACT

A major component of any training system is the instructor and the expertise he brings to the system. Because instructors are a critical resource often in short supply, automating the instructors' role, or part of that role, especially in real-time simulations is highly desirable. Automating the instructor is difficult because an instructor's knowledge embodies an understanding of a myriad of relationships including complex dynamic relations, as well as reasoning strategies, experimental knowledge, and probabilistic knowledge.

Modern Artificial Intelligence techniques currently have the ability to monitor limited aspects of training simulations. There are difficulties in handling the large temporal and dependent actions of real-time simulations. A new technique called *Template Based Reasoning* (TBR) has been developed to specifically assist in the interpretation portion of student actions in real-time simulations. In this approach, templates represent a group of attributes, actions or features that define a particular behavior of the student being monitored. How well a student's current behavior matches a particular template could provide a measure of confidence that the student is carrying out the procedure represented by that template. These templates are used to track student actions as they relate to the training goals. The student would progress through templates much as they would progress through scenarios in lessons. This direct student monitoring and evaluation can provide real-time feedback that is available for the instructor. By presenting the current template status, an instructor may view the student's progress and performance through the lessons. This is the focus of research at the University of Central Florida to assist instructor efficiency by offloading some of the workload of the instructor. This permits the instructor to concentrate on other important areas of simulation.

ABOUT THE AUTHORS

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INTRODUCTION

Traditional Artificial Intelligence (AI) programs utilize Case-Based Reasoning (CBR) or Expert Systems. CBR offers the ability to compare different groupings to determine which is the closest to the student actions, or situation. The difficulty becomes what if none of the cases are correct at the moment. If the steps are completed out of order, this must be specifically hard-wired into the CBR system. CBR has no inherent way of taking care of temporal elements. Expert systems offer the ability to join the groupings as large if-then groupings. This allows the segments to become as specific as needed. However there is still a difficulty with out of order execution, and the temporal aspects.

The solution is to take positive aspects of both systems and create a new reasoning system specifically designed to be effective in simulation environments. The new reasoning system takes advantage of the comparison techniques of different cases from CBR, while retaining the ability to set things up in an if-then format used in Expert Systems. Since neither is properly set up to be used in a simulation environment, a new presentation technique is also combined to allow for the ordering of events, and temporal aspects. This presentation technique can be considered a template. The template is a guideline for events that are described within the grouping. These groupings are compared to see which one most accurately describes the training situation, if any, and presents that information back for instructor evaluation. The system is then capable of monitoring the student actions, as a sort of second set of eyes.

There are four major elements in the monitoring and evaluation of computer based simulations: 1) How to automatically determine the optimal course of action to take under a particular set of circumstances, referred to as the "gold standard", 2) how to interpret what the student is doing; 3) how to compare what the student does compared to the gold standard, and; 4) how to control or give feedback to the students concerning their performance compared to the gold standards [Gonzalez88]. Most computer simulations have the desirable path(s) mapped out, providing the gold standard in which to compare the student's performance. The control and feedback of the simulation are the traditional strong point of the instructor. However, the difficulty in monitoring the student is trying to understand what the student is doing, and comparing that to what the student should be doing as the simulation progresses.

The first step in solving this problem is to determine the optimal course of action that the student should take under a particular set of circumstances. At least the high level steps are covered in the creation of the computer-based training scenario. The training goals must be further defined until they are specific to a certain part of the simulation. The goal breakdown will not be discussed further, since it is not the focus of this paper.

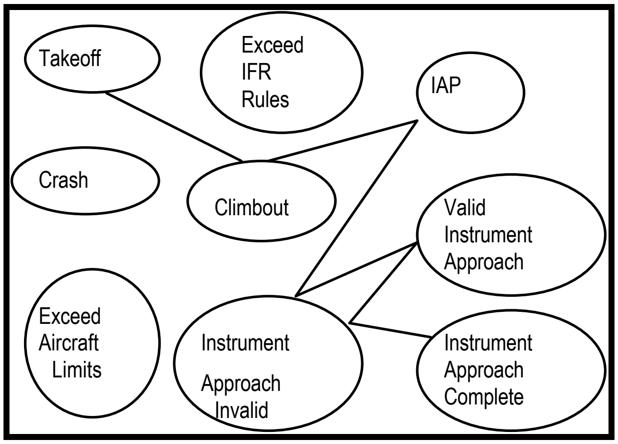
TEMPLATE-BASED REASONING

Our approach to the problems described in elements two and three above is to represent the knowledge about the gold standard as a series of templates, each of which defined a task or procedure within the training domain. These templates become a collection of generic information about the student's actions. By comparing and presenting the template information, a detailed student situational description is available for either interactive interpretation, or post simulation analysis. The combination of these templates becomes the basis for comparing the student actions across the entire simulation training session. The templates are used to guide the monitoring process through the different segments of the training scenario, looking for things that cause either training violations, or transitions to another segment of the training environment.

The training goals are broken down into different segments. Each segment corresponds to what the student is supposed to be doing during the simulation. These segments may be as coarse or as fine as needed, depending on the resolution of the tracking environment. All non relevant areas of the segment are ignored. If the student makes non-relevant training moves, they may contribute to other segments of training, which may cause the segment of interest to change. Each segment is broken down into individual templates that provide specific feedback concerning the current training state.

The following diagram shows some of the potential paths for a flight simulator. Each connected line is a potential path between templates. The lines indicate a possible path of student actions within all of possible templates.

DIAGRAM #1 TEMPLATE TRANSITIONS



The template elements are all continuously completed and removed, until one template is complete. The complete template is an accurate representation of what is happening within the training environment. However, the student may never perform all of the tasks that the template describes, but the template does describe what the student is doing. That template is most correct of the templates, and is presented back to the instructor that this is most likely the student's intentions based on his actions. This will allow for subjective events to not interfere with the overall training process, and partial training information to become useful in determining the overall training state.

Templates are composed of actions. When all of the actions are complete, the student is performing the actions described in the template header, or description. The actions within the templates may be classed as mandatory, independent, or dependent. The mandatory elements must be completed before the template may be considered for comparison. The independent events may occur any time, even before the mandatory elements have been completed, and count towards the overall probability that this template is the current student state. The dependent events either need to be completed after other events, or related to a temporal issue. The dependent templates provide the capability to describe procedural activities. If a dependent event is completed before the event it is dependent on, it is flagged for presentation to the instructor. It is then determined complete, but with the error status. This way, it contributes to the overall situational description, but points out things that are in direct conflict. These templates are used in particular scenarios to both assess student activity, and provide a level of situational awareness for the instructor concerning the student's activities.

There are other templates that either describe the boundary of acceptable and unacceptable behavior, or other aspects of the training simulation that may not be described by the templates above. These templates are classed as base templates. The templates are compared throughout the training domain, and may include activities like exceeding vehicle limitations, improper procedures under any circumstance, or procedures unrelated to the original training goals. The training simulation and goals may relate to instrument approach flight training, which involves a small and narrow focused area of the entire flight simulation envelope. The training involves mostly flight at the slower speeds of the flight envelope, but it is important to still have maximum flight speeds checked to make sure that the aircraft is kept flyable. The base templates may also include regular templates from other domains and training scenarios, providing a reuse capability.

All of the templates compete to become the leading template, that template that describes the student's actions. The only template that can be sure it describes the student's action is a complete template. Until a template is complete, a leading template is one that is "most" complete. This is described by each non mandatory element of the template containing a weighting element. The weightings for the actions are added up to create a dynamic template value. The template with the largest value is considered leading, until it is completed, or another template becomes more complete than the current leading template. This continues throughout the training simulation until a base template describes a system violation, or the simulation has completed. As a template becomes the leading template, it is presented for analysis to the instructor along with the elements that are keeping it from being a complete template. The template is not presented again until either it is complete, or is no longer the leading template. Once a template is complete, it is presented to the instructor, then disqualified from the comparison to allow for the next completed step to be analyzed.

SIMULATION EXAMPLE

The current simulation example being developed using templates involves instrument approaches. This is a phase of flight near the intended airport of landing. The aircraft is to follow a set of prescribed flight patterns, airspeeds, and configurations until such time as the pilot can see the runway, or the approach must be aborted because of minimum altitude or maximum deviations were met or exceeded. The training goal segments could be broken down into initial approach segment, Instrument Landing System (ILS) approach, Global Positioning Satellite (GPS) approach, Non-Directional Beacon (NDB) approach, final approach point, along with base templates that describe the limits of the flight boundaries. Each of the approaches is standard commercial instrument approaches and differs by the type of equipment used, procedures followed, and tolerances given for the approach.

DIAGRAM #2, EXAMPLE TEMPLATE #1

Template Title: Initial Approach Area

ACTION	EVENT TYPE	DEPEND ENCY	WEIGHT
Within 8 miles of airport	Mandatory	None	0
Altitude less than 5000 feet agl	Mandatory	None	0
Airspeed less than cruise speed	Independent	None	20
Nav freq set to airport	Independent	None	10
Airspeed within 20% of app speed	Dependent	Airspeed less than cruise speed	20

Each of the templates, such as those from diagram #1, is analyzed each frame of the simulation. Once the mandatory events have been accomplished, the template may be considered as a potential description of the student's actions. All of the templates with their mandatory events complete will be compared to see which one is *most* complete.

The following diagrams depict sample templates from the instrument flight trainer. The templates are monitored throughout the simulation, but are only valid in certain flight areas. The templates are kept invalid outside their desired areas through the mandatory elements, and dependencies on events that have not occurred yet.

DIAGRAM #3 TEMPLATE #2

Template Title: ILS Approach Start

ACTION	EVENT TYPE	DEPEND ENCE	WEIGHT
Radio Freq	Mandatory	None	5
Initial Approach Point (IAP) Altitude Minimum	Independent	None	10
IAP Altitude Maximum	Independent	None	10
Airspeed within Approach Guides	Independent	None	10
Landing Gear Down	Dependent	Airspeed	10
Flaps	Dependent	Airspeed	15
Flaps	Dependent	Gear	5
Aircraft Position (X,Y,Z) at IAP	Independent	None	5

The example templates have areas of overlap, and are continuously compared until one has a higher weighting based on the aircraft position and configuration. The template weight is the addition of the weights of the individual events within the template. The template weights are compared and the one with the highest weight has the highest probability of being the student's current action. The highest probability template is presented back to the instructor as the template-based reasoning system's analysis of the student's actions. If none of the templates is *mostly* complete then there will be no presentation back to the instructor. A mostly complete template that can be presented to the instructor is a template's total weight is greater than a predetermined value for each template. This ensures that enough of the template is complete before the reasoning system is allowed to determine that this is the potential student action.

RESEARCH EXAMPLE

The template based monitoring system described here is the focus of research at the University of Central Florida. The template based monitoring system is integrated into the flight simulation system, providing access to all of the needed student actions. These actions are parsed and compared with the instructor's recommendations.

A scientific study was designed to test the effectiveness of the template based reasoning system. It was placed in a flight simulator that was capable of instrument flight training. The student large sample was selected from pilots with little or no instrument flight experience. They were given procedure manuals for the test flight simulator, along with four practice sessions of instrument approaches. The student actions were monitored by the template based system, and a case-based reasoning system. An instrument check pilot monitored the output of both the template system and the case system. The output was compared for general accuracy, and speed of results. A group of templates that describe proper instrument approaches was compared using the TBR and the CBR system. Each system would make statements about the current training state based on the student's inputs and the training template guidelines. Invalid responses were thrown out. When each system responded similarly to a student event, the time difference between when each system came to that conclusion was statistically compared. The template-based system was significantly faster, while maintaining a higher level of accuracy than the case-based system. The accuracy was determined by comparing the number of invalid responses within each simulation.

SUMMARY

Monitoring processes that allow the instructor to either take on more students, or concentrate on other aspects of training, create a new efficiency level in the training environment. With the increased focus on using simulators to replace action equipment usage, template based monitoring systems become tools for the instructor to utilize. The end result is a training environment that is more effective. The template based system has the ability to assist the instructor, through more efficiently diagnosing the student actions. This capability is provided by organizing the training goals slightly different, and installing a template-based reasoning system. The new methodology provides an increased ability for the instructor in a simulation based environment.

Artificial intelligence has become embedded in military flight simulations [Thurman92]. Artificial intelligence techniques are being used to assist in the performance monitoring of students and real-world simulations. Many of the artificial intelligent techniques have failed to replace the instructor. Presenting information to the instructor the system creates, in effect, a "second set of eyes." This facilitates an increased capacity to view the simulation for certain events that effect reaching the training and mission goals.

The template-based reasoning system contains the training goals organized into logical states. This organization provides a monitoring process to assist the instructor in his monitoring and evaluation process. The flight instrument trainer prototype provides background for the template-based reasoning system to be integrated into a real-time simulation. In real-time simulations, the template-based reasoning system has shown to be more efficient than traditional artificial intelligence techniques. The template-based reasoning system can be used in real-time simulations to reduce the instructor's workload, and increase the overall effectiveness of the training simulation.

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