

Graphical Social Scenarios: Toward Intervention and Authoring for Adolescents with High Functioning Autism

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Abstract

Individuals with high-functioning autism spectrum disorders (HFASD) have very individualistic needs, abilities, and are surrounded by very different social contexts. Consequently, special education and therapeutic interventions often need to be adapted to a particular individual. We are interested in developing systems that can help adolescents with HFASD rehearse and learn social skills with reduced aide from parents, guardians, teachers, and therapists. We describe a social skill learning game that utilizes social scenarios. Because of the individualistic needs and abilities of our target users, we describe ongoing work on AI to assist caregivers with the authoring of tailored social scenarios.

Introduction

Individuals with autism spectrum disorders (ASD) have very individualistic needs, abilities, and are surrounded by very different social contexts. Consequently, special education and therapeutic interventions often need to be adapted to a particular individual. This makes education and intervention for ASD costly and time-consuming since it often requires working with the individual frequently on a one-to-one basis. In this paper we explore AI applications that help caregivers – parents, guardians, teachers, therapists — help their clients and loved ones with ASD.

Specifically, we are interested in developing systems that can help adolescents with high-functioning ASD (HFASD) rehearse and learn social skills with reduced aide from parents, guardians, teachers, and therapists. We target adolescents with HFASD, because they are underrepresented with respect to applicable therapies and are more likely to have complex social skill needs. For example, an adolescent with HFASD may want to go to a movie theatre without the assistance of a parent or guardian. Can a software system help that individual prepare for that social context, and furthermore help the individual learn a set of social skills that can be successfully generalized to the actual social setting?

There is not a one-size-fits-all solution to social skill learning and intervention. Our goal is to design and develop software systems that can be automatically adapted to the

particular educational and therapeutic needs of individuals with ASD. Until that challenge is overcome, systems that can help individuals with autism rehearse and learn social skills must rely on human-authored material. Working in the domain of computer-aided instruction provides two advantages. First, individuals with autism are often drawn to computers. Second, intelligent systems can be developed that, given different input parameters, achieve different social skill learning effects, tailored to an individual's needs and abilities.

In this paper, we describe a social scenario game that challenges individuals with HFASD to role-play through non-operationalized social situations – for example going to a movie theater – in a way that we believe may lead to generalization (e.g., learning). We then introduce preliminary work on intelligent systems to assist caregivers with the authoring of new, tailored scenario content.

The paper is arranged as follows. First, we describe related work from the domains of special education, autism intervention and occupational therapy, and computer-aided education. Next, we describe our scenario-based social skill learning system, provide an example walkthrough of a scenario, and describe plans for evaluation. Finally, we describe two intelligent scenario authoring technologies currently being investigated.

Background and Related Work

Impaired social functioning is the central feature of all high-functioning autism spectrum disorders (HFASD). A lack of social competency can result in significant difficulties in daily living, academic achievement, and poor adult outcomes related to employment and social relationships (Klin and Volkmar 2003; Howlin 2003). Social skills training interventions are an important part of the education of children with HFASD. Due to the lack of a recognized best practice, educators use a variety of techniques, often in combination, to teach these skills. Some common non-technological interventions are Social StoriesTM (Gray 1995), the Power Card (Gagnon 2001), and video modeling.

A review of peer-reviewed social skills interventions (Rao, Beidel, and Murray 2008) recommends that social skill intervention be aimed at children in the higher range of the autism spectrum and that the focus be on generalization of social skills. This is a key factor in the design of our

system, as we intend to present the participants with scenarios they are likely to encounter in real life.

Other experimental technological approaches to autism intervention include virtual reality simulations, and virtual peers for language learning. The Junior Detective Training Program (Beaumont and Sofronoff 2008) uses a combination of technological and non-technological practices. In this approach, social skills are operationally defined, such as engaging in reciprocal positive interactions with others. The “I can Problem-Solve” program (Bernard-Optiz, Sriram, and Nakhoda-Sapuan 2001) exposes children to animated solutions to social situations and asks the users to suggest new solutions. Tartaro and Cassell (Tartaro and Cassell 2008) and Bosseler and Massaro (Bosseler and Massaro 2003) use virtual animated characters to invite language learning. Tartaro and Cassell in particular cite the advantages of using a virtual human over actual human interactors: virtual humans have the patience to interact with individuals with ASD. Parsons et al. (Parsons, Mitchell, and Leonard 2004) created a virtual reality environment to familiarize individuals with different social settings without practicing any skills.

A Social Scenario “Game”

For our approach to computer-aided social skills education, we adopt techniques from entertainment technology research and coached problem solving. Coached problem solving (VanLehn 1996) is an approach to tutoring in which a tutor and student collaborate to solve a problem. During this process, initiative shifts back and forth: as long as the student is taking correct steps, the tutor simply indicates agreement or remains silent. If the student becomes stuck or requests help, the tutor provides hints to get the student back on a correct solution path. A technology related to coached problem solving is model tracing, in which the system attempts to track the learners at the cognitive level (Anderson et al. 1995) according to a model of correct and incorrect executions of a target skill. A common trait of model tracing systems is immediate feedback, meaning that when the learner makes an error, the system will quickly let the learner know about the mistake and help him or her repair it. Generally, the student is not allowed to continue without fixing the error.

Considering model tracing as applied to social skills, paths resemble narratives, where a narrative is simply defined as a sequence of actions is a description of how a situation unfolds. All the paths taken together resemble a branching story. A branching story is a graph structure such that each node represents a segment of narrative and a choice point. The canonical branching story systems are Choose-Your-Own-Adventure novels. However, recent research has resulted in a spate of computational approaches to branching stories (see (Riedl et al. 2008) and (Roberts and Isbell 2008) for reviews of many interactive story systems). These systems concern themselves with providing appropriate narrative content to a user immersed in an interactive, virtual story world by monitoring what the user does and responding by animating computer-controlled avatars. Our system can be considered an interactive narrative where each possible narrative is based on productive, unproductive,

and counter-productive possible executions of social skills in specific contexts. However, instead of animating avatars in a virtual world, our system responds to the user by stepping through a branching picture book of still shots. Our proof-of-concept system is set in the context of going to a movie theatre.

System Description

In our system, the user – an adolescent with HFASD – is tasked with completing a given situation, such as watching a movie in a movie theatre. The system presents the situation through picture book style images that correspond to the specifics of the situation. At every given step the system presents the user with two or more possible actions he or she can make and the user indicates which action he or she chooses. In response, the system updates the image to correspond to the new situation. Currently the images are still and the system flips to the new image once an action is taken. However, in future versions, we envision an animated system so that the user can see the transitions from one state in the situation to the next. At this stage we are uncertain how animation will impact our target user group; we currently take our inspiration from Social StoriesTM (Gray 1995), which uses cartoon figures and text-bubbles to represent speech. The options for action provided to the user are presented explicitly in randomized sequential order, indicating which button should be pressed to select that choice.

The picture book style was chosen for two reasons. First, visual symbols such as cartooning have been found to enhance the processing abilities of individuals with HFASD and to enhance their understanding of the environment (Hagiwara and Myles 1999; Kuttler, Myles, and Carlson 1998). Effectiveness of cartooning has limited scientific verification, but there is growing support for presenting social information in smaller parts or “frames” to make it easier for students to process (Rogers and Myles 2001). Second, a cartoon style makes the specific environment in which the situation is taking place more abstract. The cartoon-style approach is meant to help avoid learning of incorrect cues. Related to this, we have chosen to show the scenario from a first-person perspective, so that the user sees the environment from the same perspective as he or she might see a real environment. Further, this eliminates any confusion that could arise from seeing one's avatar from an unfamiliar perspective.

Choices can be “optimal,” “sub-optimal,” or “undesirable.”¹ We follow an approach of errorless learning, meaning that the learner is not allowed to fail. Actions that are undesirable result in the system taking the initiative to provide feedback and to allow the user to try again (with the last choice removed). Errorless learning is often used with individuals with HFASD to avoid the possibility that they acquire incorrect skills; individuals with HFASD are extremely prone to repetition so it is essential to avoid reinforcing anything other than the desirable execution.

¹In intelligent tutoring systems literature, these are often referred to as “green,” “gray,” and “red” paths, respectively.

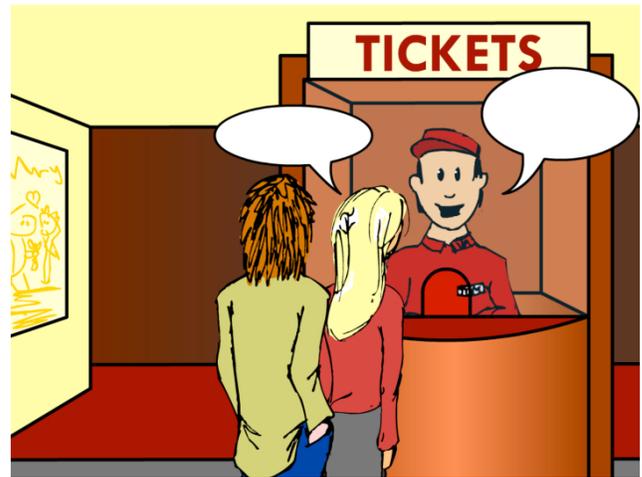
Social situations do not always unfold as planned. It is unrealistic to only rehearse social skills in ideal environments. Consequently, for some individuals, it may be beneficial for the situation to include complications. For example, in the movie theatre experience, the movie theatre could be out of tickets for the individuals preferred show. However the fact that not all individuals with HFASD have the skills or autonomy required to go to the movies without a chaperon further motivates the need for highly customized content.

Our first proof-of-concept system employing the methods described above uses the scenario of seeing a show at a movie theatre with a friend (see figure 1). The branching scenario starts with the users avatar being dropped off by a parent or guardian at a movie theatre. The scenario progresses through several situations requiring social skills. We adopt the term *obstacles* (Bruner 1990; Park 2005) because these situations prevent the user from immediate goal achievement. The social skills we are most interested in are not operationalized in the traditional sense (e.g., properly responding to a greeting), but are defined by successful navigation beyond the obstacle. The first obstacle is purchasing a ticket for a movie, which involves social skills of waiting in line, asking for a ticket to a particular show, and then exchanging money. Other obstacles may involve passing through security and finding a seat. For individuals for whom practicing handling unanticipated obstacles, our proof-of-concept scenario also includes the situation in which the show of choice is sold out. In this circumstance, the user may choose between purchasing a ticket to a different show time, a different movie, or waiting to be picked up by his or her parent or guardian.

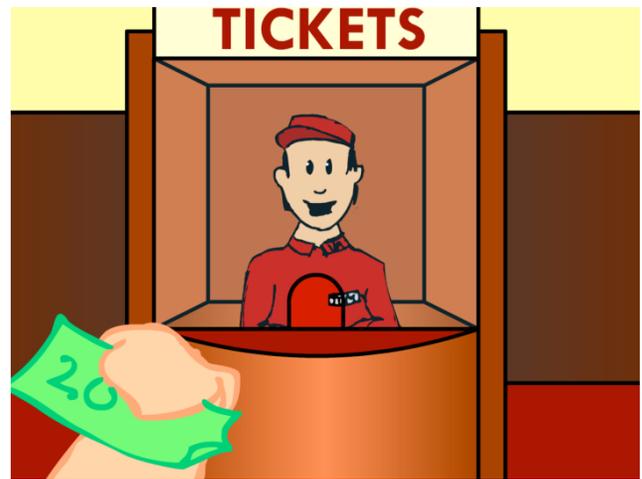
A final aspect of our system is a reflection phase, where the user has the opportunity to tell the scenario back to the system. The user is prompted to recreate the scenario and scenes from the actual scenario execution are presented as randomly shuffled puzzle pieces (see figure 1). The user must reassemble the puzzle pieces in the correct order. Reflection is often considered an integral part of learning (Chi et al. 1994; Katz, Allbritton, and Connelly 2003). We believe this will reinforce the tacit application of social skills utilized while playing through the scenario.

Testing the Approach

To determine whether branching scenarios can be effective for learning and generalizing social skills, we are currently pilot testing the intervention system with adolescents (aged 17-19) with HFASD at a nearby special-needs school. Participants will be randomly assigned to one of two groups: the active group or wait-list control group. The participants in the active group will use the computer-aided social learning system as an intervention. The participants in the wait-list use the computer system, but only ensure that they receive equal treatment should the intervention have a positive effect. That is, our experimental design allows between-group metric assessment. At the time of writing, the first experimental session has not yet been performed. Our methodological procedure is as follows.



(a) Waiting in line



(b) Interacting with sales clerk



(c) An encounter with a security guard

Figure 1: Screenshots from the prototype social skills learning system for the theatre scenario.

1. **Questionnaire for Parents.** Parents will fill out a brief questionnaire to let us know about their child's previous assessments, medications he might be taking, his birthday, how much time he usually spends on the computer, and so forth.
2. **Pre-test.** The Test of Problem Solving for Children and Adolescents (TOPS2-A) (Griswold et al. 2002) will be administered to subjects individually by researchers in a quiet area. None of the questions on TOPS2-A are directly related to the scenario in our proof-of-concept system. A researcher will read a passage aloud while the participant reads the same passage silently. The researcher will ask questions about the passage and instruct the participants to answer verbally.
3. **Active Group Intervention.** If the participant is in the active group, he or she will interact with the computer-aided social learning system. The participant will sit at a computer that has an Internet browser, a monitor, a mouse, and headphones. He or she will participate in a training session that demonstrates how to use the computer program. The system will present a series of problems in a social setting. Possible solutions will be presented. The participant will be asked to choose the best solution. When he or she chooses an appropriate solution, the story continues. The participant will receive points while playing. As a reward, the participant can use points earned towards playing other games on the computer. The participant will use the computer for 3 consecutive days to solve problems in 3 different stories. Each computer session will last approximately 30 minutes.
4. **Post-test 1.** A researcher will administer the TOPS2-A to all of the participants again. The same procedures used during the pre-test will be used during the post-test. Additionally, participants in the active group will circle ratings on a brief survey to indicate what they thought about the computer program and about being in a study.
5. **Wait-list Control Group.** If the participant is in the wait-list group, he or she will interact with the computer-aided social learning system *after the study is completed with the individuals in the active group intervention*. The same procedures will be used for the wait-list control group that were used for the active group.
6. **Post-test 2.** When the wait-list control group has completed the problem-solving tasks in 3 stories, the researcher will administer the TOPS2-A to the members of the wait-list control group again. The test will also be re-administered to the active group to test for durative effects of the intervention. The same procedures used in the pre-test and post-test 1 will be used.

Toward Overcoming the Content Authoring Bottleneck

The current proof-of-concept system has three hand-authored scenarios. To motivate the need for AI assistance for scenario authoring, consider the scenario for going to a movie theater. The content alone took 80 person hours to develop. This does not include time to learn Flash or the time

to import the art assets into Flash. It is well-established that branching story content increases content authoring time geometrically with the number of branching points and the number of possible branches per point (Bruckman 1990; Riedl and Young 2006). That is, for every point in which the user can make a decision, the amount of content that must be produced is multiplied by the number of decisions that can be made (assuming no loops). Our simple proof-of-concept scenario – going to the movie theatre – required 25 images to be produced.

Given the complexity of producing content, there is no way that a few trained expert content producers can create customized learning material for all potential consumers. We refer to this phenomenon as the *authoring bottleneck*. When applied to healthcare, one can talk about overcoming the authoring bottleneck as *scaling up*, *scaling in*, and *scaling out* healthcare delivery (Robertson et al. Forthcoming). *Scaling up* refers to the delivery of products/services to greater numbers of people. *Scaling In* refers to customization of products/services. *Scaling Out* refers to accessibility of products/services. For our work on HFASD intervention, we are particularly concerned with scaling up and scaling in.

How do we scale up and scale in delivery of our social skills intervention? We believe this problem motivates the application of artificial intelligence. Artificial intelligence can be used to automate certain tasks so that they are completed faster, more accurately, more efficiently, more safely, or more often. In this paper we consider how AI can assist in the generation of branching scenario content and the production of graphic visualization of scenario content. Our goal is to use these artificial intelligence techniques to make it trivial for non-experts to produce novel scenario content customized to adolescents with HFASD.

For our system to be useful, we must lower the bar of content authoring to the point that parents, guardians, and teachers can produce useful social skill scenarios for the individuals with HFASD that they care for. In the case of our computer-aided social skill learning system, there are several complications with regard to authoring content:

- **Animation** – we cannot assume that our target authors have the necessary artistic abilities.
- **Authoring branches** – we cannot assume that our target authors will be able to set up sufficiently complicated scenarios with branching structures required to step through all the necessary permutations of situations. Further we cannot assume that our target authors will be able to create equally compelling (or error-free) content for all branches.
- **Pedagogical correctness** – we cannot assume that our target authors know how to create scenarios that are pedagogically appropriate (for example, using errorless learning).
- **Skill correctness** – we cannot assume that our target authors can correctly represent the social skills that they desire others to learn.

In the next sections we discuss our expectations for caregiver authoring, followed by two artificial intelligence tech-

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Action: Wait-In-Line (?user, ?place)
precondition: at(?user, ?place)
              has-line(?place)
              not (inside(?user))
effect: not (has-line(?place))

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Figure 2: Declaration for the event “Wait in line.”

nologies that can be used to assist with the authoring of scenario content.

Caregiver Scenario Authoring

In the near-term, we do not envision a system that is capable of fully automatically generating social scenarios. However, with a sufficiently comprehensive model of social contexts, we envision a system where caregivers describe social situations in enough detail that the system can complete the branching scenario structure. At a minimum, we require human scenario authors to provide the following:

- Information about the target individual with HFASD.
- An event sequence. This is a prototypical script for how a particular type of social scenario should occur.
- Specific examples of things that go wrong (e.g., obstacles) and negative outcomes.

The event sequence is key, it is a linear description of the social situation. Note that we are not asking the caregiver to provide all possible branches, but a single path that is the expected sequence. For example, this could be a description of the sequence of events that occur when everything goes right at a movie theatre. The events must correspond with a library of events that they system knows about. In our approach, we encode a model of the virtual world in a STRIPS-like declarative language that describes events in terms of preconditions – conditions in the world that must be true for an event to occur – and effects – how world conditions are different after an event. Figure 2 shows how the event “wait in line” is encoded.

We assume the domain model has already been created by domain experts. Consequently, end-user authoring is analogous assembling building blocks – selecting actions and assigning characters, places, and things. However, the social scenario game requires branching sequences with choice points and feedback for errorless learning. We do not believe it is reasonable to ask caregivers to create the entire branching structure. Instead, we use the linear event sequence and the other pieces of information listed above to automatically complete the branching scenario structure.

Branching Scenario Authoring Assistance

The primary data structure of our system is a graph, such that each node in the graph is a situation that corresponds to an image. Directed arcs between nodes represent decisions that the individual with HFASD can make at each node.

Anecdotally, we know that people can write non-branching narratives, but that branching structures tend to cognitively overload the human author. However, if one can

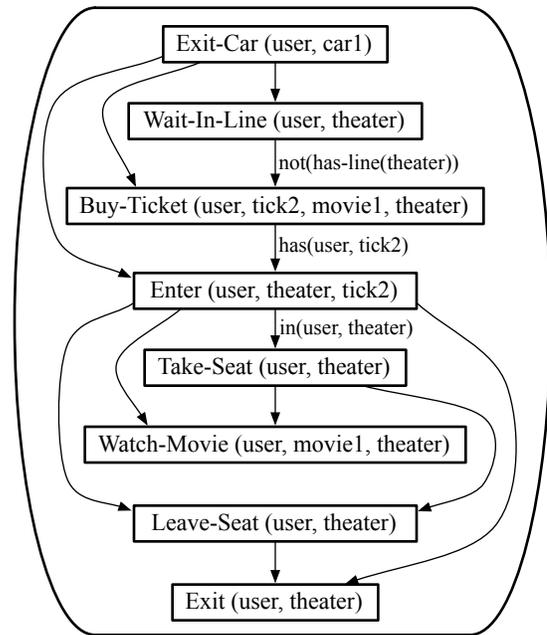


Figure 3: A sample narrative plan for the movie domain.

describe the behavior of the system with a few number of non-branching narratives – in this case, descriptions of prototypical theatre experiences – an AI system can use this information to generate branching structures. Riedl and colleagues (Riedl, Saretto, and Young 2003; Young et al. 2004; Riedl and Young 2006; Riedl et al. 2008) describe a technique, called *narrative mediation*, for automatically generating branching narrative structures. Specifically, Riedl et al. (Riedl et al. 2008) describe an adaptation to narrative mediation in which a single prototypical non-branching narrative is provided as input to an AI algorithm that produces possible alternative branches based on a similarity metric.

Overview of Narrative Mediation In narrative mediation, non-branching narratives are represented as partially- or totally-ordered plans (c.f., (Weld 1994)). Planning has been demonstrated to be a practical technology for generating narrative content (Meehan 1976; Lebowitz 1987; Young 1999; Riedl and Young 2004; Riedl 2004). Operators in a narrative plan are events in the narrative and links represent causal relationships between events (i.e., there is a link if one event is causally necessary for a temporally successive event to take place). Figure 3 shows an example narrative plan for a prototypical movie theatre experience. The square boxes are actions/events, and the arrows between events are causal relations (only a few are labeled with their respective conditions).

Our AI system requires (a) one or more prototypical narratives represented as a partially-ordered plan, (b) a domain model of the world that enables a planner to solve social scenario goals from a range of state configurations, (c) and a favorable outcome state. For now we assume that this knowledge can be engineered *a priori* and may or may not include

case descriptions of common ways in which social situations unfold. Scenarios are individualized by incorporating knowledge about the client – an adolescent with HFASD – into the world description. This forces the narrative generator to take such individualistic elements into consideration.

In narrative mediation, an AI system automatically analyzes the causal structure of the narrative plan, looking for points at which a users actions can undo causal relationships. This amounts to a set of “what-if” experiments in which the AI system proposes “what if the user were to perform action *a* at time *t*?” If the answer is that the original narrative plan could not continue, the AI system invokes a planning-based narrative generator to determine whether the narrative can be restored should the user were to take the hypothetical action. This alternative narrative plan is a branch designated for handling the contingency of the users action. In Riedl et al. (Riedl et al. 2008), repaired narratives are preferred that are as similar to the original as possible. The process is recursive: each new narrative is inspected for points in which branching can occur until no new branching points are identified or until a depth bound is reached.

Authoring with Narrative Mediation Narrative generation (c.f., (Meehan 1976; Lebowitz 1987; Turner 1992; Riedl and Young 2004)) is in its relative infancy. However, for social skills training, the goal is not to achieve dramatic effects, but to demonstrate pedagogical and skill correctness. In that respect, the desired outcome state is the successful completion of a social skill and a planner must achieve the outcome state.

We leverage the linear manual process of describing one or more prototypical social scenarios. As described earlier, we believe it reasonable for a caregiver to select and instantiate actions to create event sequences. However, this does not provide the complete partial-order plan required for narrative mediation. We first pre-process the manually authored event sequence by automatically filling in the causal relationships. We employ a partial-order planner (Weld 1994) – we seed the initial plan with the temporally ordered sequence of manually authored events and indicate that the plan is flawed until all preconditions on actions are satisfied. This has the side-effect of the planner filling in any missing events necessary for causal completeness. Once a plan is found with a complete set of causal relationships, we employ the narrative mediation process described above to generate the contingency plans.

With narrative mediation, we can leverage a linear manual process of describing one or more prototypical social scenarios, and produce an exponential number of ways in which a social scenario can unfold. If the human author creates multiple linear descriptions of ways a scenario can unfold, we can create a tree with prefix matching. That is, we merge two linear narratives until an event occurs that does not match. Once we have fleshed out the tree of branching scenario paths using narrative mediation, the human author can then inspect the branching structure for errors; it is easier to edit a branching scenario than to author one from scratch. To facilitate editing, each complete narrative – a path from the initial state to the outcome state found by traversing the

branching scenario graph – can be presented linearly. The process of transforming a branching narrative into *n* non-branching narratives is straightforward.

Errorless Learning Branches The AI process we have described so far does not consider errorless learning. To account for errorless learning, we need to generate “optimal,” “sub-optimal,” or “undesirable” branches. The techniques described above can only generate “optimal” and “sub-optimal” narrative branches, but does not classify those branches.

To classify generated branches, we observe whether the new branch is a novel sequence for achieving the desired outcome, or whether the new branch is a minor variation of the narrative of the parent branch. Minor variations are “sub-optimal” but not “undesirable.” One can think of the branch as a repair to the originating branch in the sense that the user has performed an action that is not the most effective for reaching the desired outcome, but is not harmful. Each “sub-optimal” branch begins with a special action that explains, with text, the reason why the action that was taken is not the best choice. Currently, we require the human author to write the explanation. However, in future work, we may be able to automatically generate the explanation by comparing the branch to the original path.

To generate “undesirable” branches, our system must do extra work. Because narrative mediation is based on planning, it only results in paths – narratives – that successfully achieve the desired outcome state. For the purpose of assisting with the authoring of social skills scenarios, we extend narrative mediation to generate undesirable branches. We are currently experimenting with modifications of the Narrative Mediation technique. The branching scenario generation algorithm has the following steps.

Given one or more sample narrative in partial-order plan formalism, stepping through the social scenario, first create an initial skeletal tree by identifying common prefixes. Branches occur where narratives diverge. For each branch, use a “what-if” test to determine whether the user can perform an action that makes it impossible for the scenario to continue as described. For each user action that threatens the narrative branch, generate a new branch. The process continues until no new branches can be identified or until a pre-defined limit is reached. The generation process is where errorless learning must be addressed. Given a set of undesirable outcome states (for example, the user is kicked out of the theatre for being disruptive) and for each potential branch-disruptive user action, we use a partial-order planner to determine whether the undesirable outcome can be achieved. If it can, we label the new plan as an “undesirable branch.” However, instead of adding the plan to the tree as a branch, we generate a discourse explanation (Moore 1990) for why the course of action should not be pursued. Explanation generation is future work, but we envision using an approach to narrative discourse generation used in (Riedl 2004).

If an undesirable branch is not found, we employ the conventional narrative mediation approach of using planning to generate a new narrative branch that repairs any damage

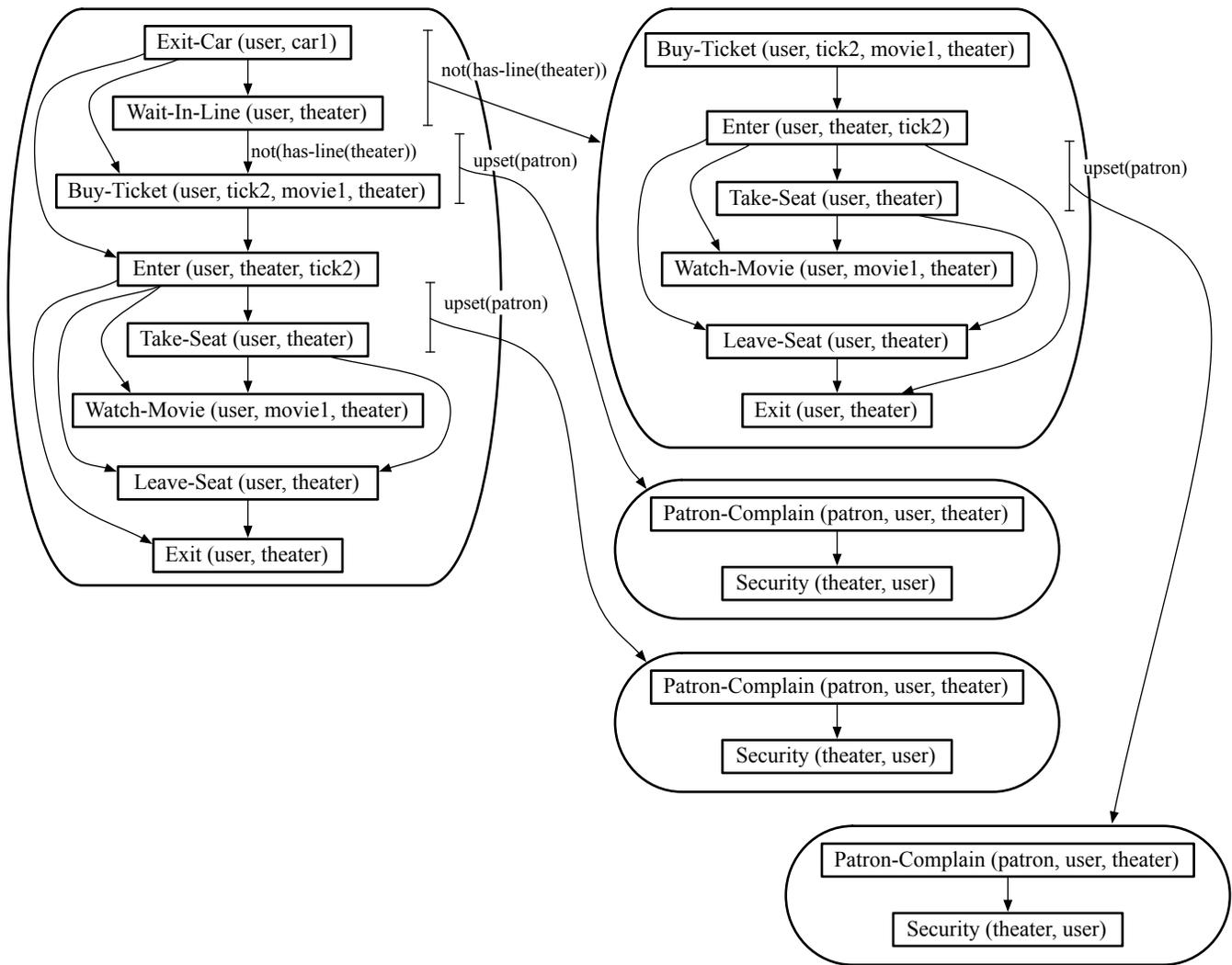


Figure 4: A sample narrative mediation tree for the movie domain.

caused by the potential branch-disruptive user action. In our new framework, we regard this branch as “sub-optimal” but otherwise acceptable.

Example An example of a narrative mediation tree for the theater domain is shown in Figure 4. Each large box is a narrative plan. The left-most narrative is the given narrative plan describing the prototypical theatre-going experience. The sequence of actions in the prototype was authored manually, but the links between actions were automatically inserted by the planner. This sequence, and information about good and bad outcomes, is the only information provided by the author.

Successive narrative boxes are branches that occur if the user deviates from the parent plan. The short branches are “undesirable” branches – we have not invoked explanation generation to replace these branches with explanations. The arrows between narratives represent intervals in which the user can deviate from the narrative and the condition that

causes the deviation. For example, if the user performs an action that causes the theater to not have a line (perhaps by cutting in line), then the system transitions to a new narrative where waiting in line is not necessary. However, certain conditions can trigger patrons becoming upset, causing further transitions.

Figure 4 shows only a few of the hundreds of branches automatically generated for this simple scenario. Note that most branches are small deviations from the parent. The branch in which a patron complains was generated by the errorless learning handler described above and would normally be rendered into an explanation instead of executed. During execution, if the user chooses an “undesirable” branch, the explanation is given and the user is allowed to go back and try again. The previous choice is disabled so that the user cannot repetitively make the same mistake.

Animation Assistance

At first glance, the problem of assisting authors with animation does not seem challenging. Let us suppose that there is an authoring interface in which the human author can select from scenes and characters templates. It is not unreasonable to assume that a human content author can use such an interface to create an image to correspond to a non-branching scenario. However, because of the combinatorial explosion that comes with branching scenarios, asking a human to manually produce images for each possible narrative branch is unrealistic. However, the selection and composition of graphical templates can be automated. Elson and Riedl (Elson and Riedl 2007) describe a system – Cambot – that, given a description of a scene and dialogue, selects characters, locations, and camera angles for the composition of 3D animated movies.

Cambot treats input – a script consisting of actions and dialogue with possibly incomplete location, blocking, view, and scene specifications – as a set of constraints that must be satisfied in order to find a sequence of shots that cover all the beats. A *blocking* is a configuration of actors on a stage. For example, a conversation between two characters may require the characters to be facing each other at a particular distance away from each other. A *beat* is a minimal element of visual storytelling, typically involving a single action and single reaction. In the case of our social scenario “game,” the script is the event sequence in a narrative branch and blocking, view, and scene specifications are derived from plan operator metadata. The input constraints define a search space comprised of compatible locations, blockings, and shots.

Cambot uses a combination of breadth-first search and dynamic programming to search this space to find the highest-scoring combination of locations, blockings, and shots that cover each beat. Score is computed relative to the degree of satisfaction of user-provided (or default) aesthetic constraints. The result of this process is a sequence of shots, blockings, gestures and dialogue acts, along with precise timing information, that can be sent to a visualization engine for final rendering. Currently, our visualization engine is a modified version of Unreal Tournament™. Figure 5 shows example shots from an animation sequence generated by Cambot for a simple script involving dialogue between two characters.

We envision a version of this technique for the automated graphical rendering of situations described by the human author or generated by the narrative generator. The system would be constrained to produce only first-person perspective shots with no camera movement, effectively producing the still image we currently desire for our prototype.

Current Status and Future Work

The social scenario intervention game is complete and currently undergoing evaluation, as described in Section 2. Narrative mediation has been developed for previous projects (Young et al. 2004; Riedl et al. 2008). The errorless learning extensions to narrative mediation have been implemented and tested out on the theatre domain. More work is required to make a more complete world model that can be used for



Figure 5: Shots from an animation generated by Cambot.

more than just the one social scenario. The Cambot cinematography system has been implemented previously (Elson and Riedl 2007). Future work consists of modifying Cambot for use in the social scenario intervention and connecting the output of the narrative generation to Cambot.

The feasibility of our approach requires a better understanding of caregiver authoring. While we feel we have an approach that makes authoring significantly easier than the alternative – complete specification of branching scenarios and production of associated images/animations – we need to further understand whether our approach will make caregiver authoring easy enough to be adopted into existing practices. In the future, we intend to test our AI system on representative caregivers (parents, guardians, teachers, and therapists) to assess their authoring needs, time to complete novel linear social scenarios, and degree to which the AI system correctly generates the complete branching graph structure with respect to pedagogy and skill.

Conclusions

The population of adolescents with high functioning autism spectrum disorder (HFASD) is growing. Many of these individuals can function effectively and autonomously, but need assistance to handle the complexities of society. We propose an approach combining intelligent tutoring with branching narrative graphs in a system for (a) rehearsal of social situations, and (b) learning to generalize non-operationalized social skills and problem solving. The primary intervention is delivered in the form of a social scenario “game” that challenges individuals to complete tasks involving social situations.

In our particular approach to rehearsal and generalization of social skills, we run into a challenge that is also common to other intervention and therapy strategies with regard to large-scale distribution: customization and individualization of interventions, therapies, and educational content does not scale. Specifically, this material must be manually configured, and it often must be administration manually. We believe this is a bottleneck faced by all HFASD interventions due to the individualistic nature of ASD in general. We hypothesize that the role of artificial intelligence in HFASD intervention is in the overcoming of bottlenecks that limit *scaling up* and *scaling in*. Our approach is to use artificial intelligence to lower the manual authoring burden to the point where customization and administration of interventions, therapies, and instructional materials can be handled by parents, guardians, and teachers.

References

- Anderson, J. R.; Corbett, A. T.; Koedinger, K. R.; and Pelletier, R. 1995. Cognitive tutors: Lessons learned. *The Journal of the Learning Sciences* 4(2):167–207.
- Beaumont, R., and Sofronoff, K. 2008. A multi-component social skills intervention for children with asperger’s syndrome: The junior detective training program. *The Journal of Child Psychology and Psychiatry* 49(7):743–753.
- Bernard-Optiz, V.; Sriram, N.; and Nakhoda-Sapuan, S. 2001. Enhancing social problem solving in children with autism and normal children through computer-assisted instruction. *Journal of Autism and Developmental Disorders* 31(4):377–384.
- Bosseler, A., and Massaro, D. 2003. Development and evaluation of a computer-animated tutor for vocabulary and language learning in children with autism. *Journal of Autism and Developmental Disorders* 33(6):653–672.
- Bruckman, A. 1990. The combinatorics of storytelling: Mystery train interactive.
- Bruner, J. 1990. *Acts of Meaning*. Cambridge: Harvard University Press.
- Chi, M.; de Leeuw, N.; Chiu, M.; and LaVancher, C. 1994. Eliciting self-explanations improves understanding. *Cognitive Science* 18:439–477.
- Elson, D. K., and Riedl, M. O. 2007. A Lightweight Intelligent Virtual Cinematography System for Machinima Production. In *Proceedings of the 3rd Conference on Artificial Intelligence and Interactive Digital Entertainment (AIIDE)*.
- Gagnon, E. 2001. *The Power Card: Using Special Interests to motivate Children and Youth with Asperger Syndrome and Autism*. Autism Asperger Publishing Company.
- Gray, C. 1995. *Social Stories Unlimited: Social Stories and Comic Strip Conversations*. Jenison, MI: Jenison Public Schools.
- Griswold, D.; Barnhill, G.; Myles, B.; Hagiwara, T.; and Simpson, R. 2002. Asperger syndrome and academic achievement. *Focus on Autism and other Developmental Disabilities* 17:94–102.
- Hagiwara, T., and Myles, B. 1999. A multimedia social story intervention: Teaching skills to children with autism. *Focus on Autism and Other Developmental Disabilities* 14:82–95.
- Howlin, P. 2003. Outcome in high-functioning adults with autism with and without language delays: Implications for the differentiation between autism and asperger syndrome. *Journal of Autism and Developmental Disorders* 33:3–13.
- Katz, S.; Allbritton, D.; and Connelly, J. 2003. Going beyond the problem given: How human tutors use post-solution discussions to support transfer. *International Journal of Artificial Intelligence in Education* 13:79–116.
- Klin, A., and Volkmar, F. 2003. Asperger syndrome and external validity. *Child and Adolescent Clinics of North America* 12(1):1–13.
- Kuttler, S.; Myles, B.; and Carlson, J. 1998. The use of social stories to reduce precursors to tantrum behavior in a student with autism. *Focus on Autism and Other Developmental Disabilities* 13:176–182.
- Lebowitz, M. 1987. Planning stories. In *Proceedings of the 9th Annual Conference of the Cognitive Science Society*.
- Meehan, J. 1976. *The Metanovel: Writing Stories by Computer*. Ph.D. Dissertation, Yale University.
- Moore, J. 1990. *Participating in Explanatory Dialogues*. Cambridge, MA: MIT Press.
- Park, M. 2005. *Narrative Practices of Intersubjectivity: An Ethnography of Children with Autism in a Sensory Integration Based Occupational Therapy Clinic*. Ph.D. Dissertation, University of Southern California.
- Parsons, S.; Mitchell, P.; and Leonard, A. 2004. The use and understanding of virtual environments by adolescents with autistic spectrum disorders. *Journal of Autism and Developmental Disorders* 34(4):449–466.
- Rao, P.; Beidel, D.; and Murray, M. 2008. Social skills interventions for children with asperger’s syndrome or high-functioning autism: A review and recommendations. *Journal of Autism and Developmental Disorders* 38(2):353–361.
- Riedl, M. O., and Young, R. M. 2004. An Intent-Driven Planner for Multi-Agent Story Generation. In *Proceedings of the 3rd International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS)*.

- Riedl, M. O., and Young, R. M. 2006. From Linear Story Generation to Branching Story Graphs. *IEEE Journal of Computer Graphics and Animation* 26(3):23–31.
- Riedl, M. O.; Stern, A.; Dini, D. M.; and Alderman, J. M. 2008. Dynamic Experience Management in Virtual Worlds for Entertainment, Education, and Training. *International Transactions on System Science and Applications, Special Issue on Agent Based Systems for Human Learning and Entertainment* 4(2).
- Riedl, M. O.; Saretto, C.; and Young, R. M. 2003. Managing Interaction between Users and Agents in a Multi-Agent Storytelling Environment. In *Proceedings of the 2nd International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS)*.
- Riedl, M. 2004. *Narrative Generation: Balancing Plot and Character*. Ph.D. Dissertation, North Carolina State University.
- Roberts, D. L., and Isbell, C. L. 2008. A survey and qualitative analysis of recent advances in drama management. *International Transactions on Systems Science and Applications* 3(1):61–75.
- Robertson, J.; DeHart, D.; Tolle, K.; and Heckerman, D. Forthcoming. Healthcare delivery in developing countries: Challenges and potential solutions. In *The Fourth Paradigm: Data-Intensive Scientific Discovery*. Microsoft Research.
- Rogers, M., and Myles, B. 2001. Using social stories and comic strip conversations to interpret social situations for an adolescent with asperger syndrome. *Intervention in School and Clinic* 36:310–313.
- Tartaro, A., and Cassell, J. 2008. Playing with virtual peers: bootstrapping contingent discourse in children with autism. In *Proceedings 2008 Int. Conf. of the Learning Sciences*.
- Turner, S. 1992. *MINSTREL: A Computer Model of Creativity and Storytelling*. Ph.D. Dissertation, University of California, Los Angeles.
- VanLehn, K. 1996. Conceptual and meta learning during coached problem solving. In *Proceedings of the 3rd International Conference on Intelligent Tutoring Systems*.
- Weld, D. 1994. An introduction to least commitment planning. *AI Magazine* 15.
- Young, R. M.; Riedl, M. O.; Branly, M.; Jhala, A.; Martin, R.; and Saretto, C. 2004. An Architecture for Integrating Plan-Based Behavior Generation with Interactive Game Environments. *Journal of Game Development* 1:51–70.
- Young, R. 1999. Notes on the use of plan structures in the creation of interactive plot. In *Proceedings of the AAAI Fall Symposium on Narrative Intelligence*.