

## **Developing a Virtual Piano Playing Environment**

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### **Abstract**

In this paper the framework for a multimedia platform called ADRI is described which aids in playing the piano. A 3D-piano with visualisation of notes was built in a virtual environment and connected with a real synthesizer using Midi to interact with a user. Multiple users can play together on the virtual piano in this 3D environment from different locations.

Multiple agents were made, each with its own independent functionality within the multi-agent platform. Using this system an artificial piano teacher can be developed further to give the environment more educational value and to aid a real piano teacher with his lessons. The environment can also be used as an administrative tool or knowledge base with lessons, songs or other information needed for piano playing.

# Developing a Virtual Piano Playing Environment

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## Abstract

*In this paper the framework for a multimedia platform called ADRI is described which aids in playing the piano. A 3D-piano with visualisation of notes was built in a virtual environment and connected with a real synthesizer using Midi to interact with a user. Multiple users can play together on the virtual piano in this 3D environment from different locations.*

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## 1. Introduction

Using virtual environments, it is possible to do things that cannot be done in the real world, such as viewing places that cannot exist in the real world. Combining these worlds with different forms of human computer interaction like (written) natural language, data gloves or by connecting a musical instrument to a computer, makes it possible to develop new tools that can be used in education. Using music as a medium for this interaction can make the use of the computer in education more playful and can be attractive for a bigger audience. In the ADRI project teaching in an educational environment with alternative media for learning is investigated.

The Parlevink group researching language, knowledge and interaction at the University of Twente combines research on human-computer interaction, dialogue systems, autonomous agents and virtual worlds. Our group has built the VMC (Virtual Music Centre), which is a replica of an existing music centre and serves as an environment to experiment with multi-modal interaction with agents or other visitors to this virtual world [1]. In this context JACOB was built, an instruction agent that

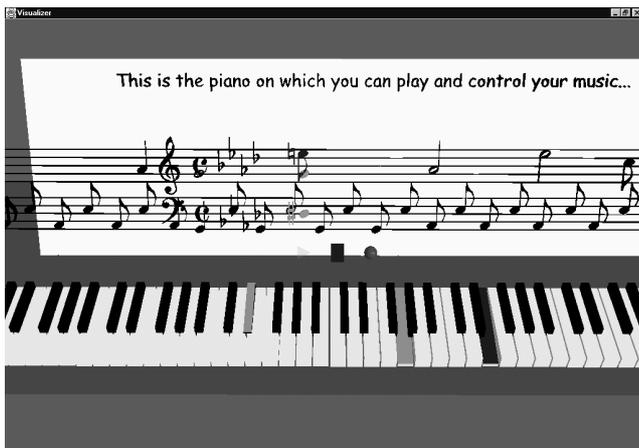
helps the user to solve a mathematical puzzle in virtual reality [2]. Based on our experience with Jacob, the idea arose for creating ADRI (Artificial Didactic Recital Instructor), a system intended to aid people learning to play the piano. By combining a 3D-world with a virtual piano, a real synthesizer, a simple knowledge base and expert algorithms an environment has been built in which one can play on a 3D-piano. This environment can be developed further so it can be used and evaluated by experts and users.

The goal of the ADRI project is to design an agent based technical framework for a learning environment combining different input devices, domain knowledge about playing the piano and virtual reality to serve as a tool in education. By removing or adding agents with different functionalities, the environment can be altered according to different needs of a user, student or teacher.

The organisation of this paper is as follows. First, in section 2 the implemented virtual environment is described in which one or more users can play on a 3D-piano using a synthesizer that is connected with a PC. In section 3 the ideas on the educational aspects of playing the piano are explained. After this the description of the architecture of the multi-agent platform in which the different functionalities are combined is given in section 4. Section 5 presents a few examples of how the system can be used. The paper concludes with a section about possible new developments and future work.

## 2. Music and piano playing

Music can be used as an appealing application area for interacting with a virtual world. It seems more interesting in our opinion to focus on the real-time interaction with a player then making attempts to simulate virtual performers making music [3]. Making and hearing music while seeing this music in different forms on a screen can be very stimulating and is an interesting extension of more traditional modalities in human-computer interaction. Playing together with more people on different or similar instruments can give a whole new dimension to making music. Even if there are no real



**Figure 1. The Virtual Piano Environment.**

people to play with, there can be artificial players and teachers who can demonstrate the basics or improve existing skills.

In ADRI the piano (synthesizer) has been chosen as instrument of demonstration, because of its capabilities to connect its discrete output to a PC using the Midi protocol. With other instruments such as snare or brass instruments it is harder to interpret which notes are played. As long as the synthesizer is considered to be a tool to convert the user actions to Midi rather than a real piano, the quality of the sound produced by the computer from the Midi is not that important. In the following sections two aspects of the framework of ADRI are described in greater detail: the virtual environment and the MIDI interface.

### 2.1. Playing virtually

The 3D piano was constructed using the Java3D API. It can be played using either a real synthesizer connected to a PC, or by using a mouse to click on the virtual piano keys shown on screen, as shown in Figure 1. The Java3D API was used to enable us to combine the piano with other instruments such as the virtual drummer developed in our group [4], so that people can play together virtually in a band [5]. It gives the possibility to display the different types of notes that are played and it has functions to manipulate Midi files using the piano or algorithms rather than manipulate individual notes of a song [6]. It will be easy to make different visualisations of the notes, using e.g. with klavarscribo or playful animations for younger students. It is possible to play 'quatre mains' with multiple users at different locations on the same 3D piano or to turn the environment into a game in which for instance one player has to copy the other player to earn points. The virtual piano can be

situated in any Java 3D multi-user environment or used as a stand-alone system.

### 2.2. Using Midi

As already was explained above, the 3D piano cannot only be played with the mouse but also using a real synthesizer with Midi output. This synthesizer delivers Midi events to the PC, which give information on specific actions taking place on the keyboard, for example the velocity of a key that is being pressed, resulting in volume of the sound. These events can be used as input for the 3D piano or for visualisation of notes. Other instruments with a Midi output can be added to the environment without having to change the existing system.

One difficulty in this approach of capturing Midi to create input for the teacher is the different way in which music is handled. A real piano teacher can analyse the sound that is an interpretation of the music on a sheet. But in this case Midi events captured from the synthesizer have to be translated into sounds as well as into a representation for the notes on the staves. Information is lost in the latter, which makes it hard to analyse the playing. Technically, it is just the other way around, when the sounds are converted into sheet music, instead of sheet music into sounds.

Another difficulty is that the artificial teacher cannot correct the physical movements of the hands playing the piano; it only knows which keys are being pressed on a specific moment in time. It can only demonstrate *which* keys to play, for example by colouring the keys on the 3D piano. Therefore a real (human) teacher should remain involved when using the system.

## 3. Educational programs

Other educational programs have already been made using multimedia and real input from a synthesizer to teach piano playing [7], but without using virtual reality or agents. The ADRI environment serves as a prototype in which these technical possibilities can be demonstrated by combining virtual reality, different input devices, agent technologies and educational strategies. This prototype is to be demonstrated to and tested by users, both students and teachers, whose opinions and knowledge will improve the system. This feedback on the prototype can be used to extend the system with real domain knowledge and educational strategies instead of the example lessons currently present. In the next two paragraphs more is explained about how this knowledge and these strategies can be put into the system.

### 3.1. Knowledge

The knowledge present in the environment is divided among different agents. In ADRI an agent is a process in the computer that is given a specific task. Each agent has a special expertise and knowledge domain and can give information or act when it decides when appropriate. This knowledge can be used on demand of users, other agents or on the agents' own initiative. The databases with knowledge used by such an agent can be altered or improved by human experts or in a later stage by the agent itself or with the help of other active agents. Human experts can add knowledge about scales, chord recognition, songs and tempo to ADRI. Recorded Midi songs could be analysed and stored for later use to keep track of the progression of students. In the future an agent might search in an existing music database linked to the system to get more knowledge or teachers could share information, using ADRI with other teachers by using the environment as a communication network and tool to exchange lessons or examples.

### 3.2. Strategies

Different strategies in teaching piano playing have to be available and used in the right situation. For example, more experienced students can be presented more difficult topics and formal notation of notes. Furthermore, students with different levels of experience might have different motivations to learn playing or may learn quicker using a different attitude. Previous work on educational programs that can decide how to proceed within a lesson-structure depending on the attempts of students is described in [8]. In the current framework, different agents can be used to experiment with different strategies such as the one referred to above, or combinations of strategies.

Just repeating some scales or rests as an exercise, in product oriented learning is not the most motivating thing to do. Process oriented learning can be applied by showing the students how to play a specific song and will cover most of the necessary topics in piano playing as well. The exploratory learning strategy is more difficult to apply in which the students could have the possibility to choose their own song or topic that they wish to learn using the visualisation and information given to them based on their own level of experience. The choice of how to proceed a session can be made by the student, the artificial or the real teacher depending on different conditions that can eventually be stored in the system. Different agents with different strategies can be made to experiment with different strategies in learning.

## 4. Multi-agent Platform

Implementing all the requirements into one agent is complex and makes it difficult to add more functionality. By distributing the problems to more than one agent, the system becomes more flexible but requires a platform in which the agents can communicate in the same way. Therefore a multi-agent platform is used [9], which also makes it possible to implement different interfaces for the users, both students and teachers, and the possibility to distribute parts of the system among different machines by using more than one agent.

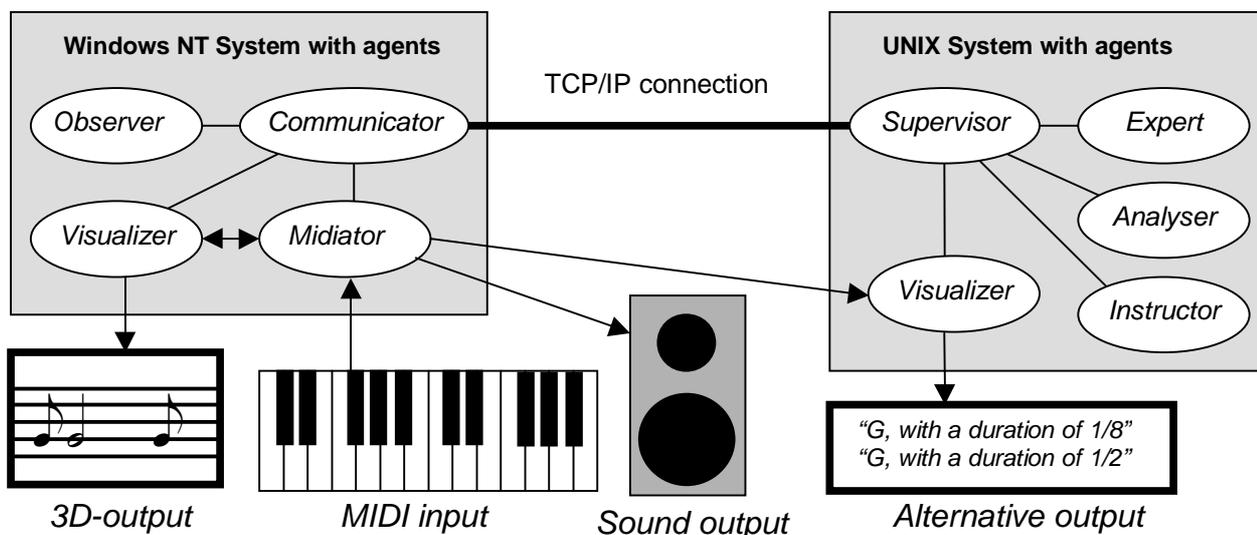
Different agents are assigned different functions and combined in one instructional system [10, 11]. In the case of ADRI the agents are just different independent processes, which do not necessarily need to have a physical appearance in the virtual world. In other stages of the project it could be decided to give the instructional agents a virtual representation in the 3D world, but at the moment that does not add to the main goal of building the framework. The agents can send messages to other agents or different groups of agents that can use them to achieve their goals. By creating, altering, adding or removing agents in the platform the functionality can be changed.

### 4.1. Different agents

In this framework an agent can be made reactive, proactive, intelligent or simply act as an interface to a user depending to the need of the user. In this prototype several minimal implementations of agents were made, but activated together these already have enough capabilities to use the system.

Several minimal agents are for example a '*Visualizer*', which controls the display of the 3D world or alternative visualisations, a '*Mediator*' to capture or sound music that is being played and an '*Expert*', which has knowledge about different songs and chords. The '*Analyser*' can convert existing Midi songs and augment them with specific features that are useful for other agents or users. For the educational part a '*Navigator*' can be used which decides on the next step to take in the curriculum so that the '*Instructor*' can take that specific part of the lesson and guide a student in learning it. The work and progression of the student can be commented by the '*Feedback*' agent and modelled by the '*Observer*' for eventual evaluation. Other distributions of functionality among agents can be useful as well, but that can be something to learn when using the system.

Finally there is the '*Supervisor*', which acts as a tool to control and visualise the different agents and has the possibility to send user made messages to agents or groups of agents. This '*Supervisor*' communicates with one or more '*Communicators*' which can link different systems together. The '*Supervisor*' provides an abstract



**Figure 2. The connections between agents on different systems in the framework.**

view of the platform. In this graphical user interface the currently activated agents and how they are connected with each other are represented. Remote agents can be dynamically added or removed from the platform through the 'Supervisor'. Different unique properties can be changed and agents can be added as a member to different groups of interest.

#### 4.2. Communication

The agents are not aware of each other's existence and react differently according to the information they get through the exchange of messages. This makes it easy to change the system during run-time to satisfy the demands needed on that moment. An 'Expert' can be invoked when a specific song is needed. Agents have to subscribe to a group interested in the same information to receive messages containing that specific information. These messages are being multicast to this group throughout the platform without bothering who is receiving them. This reduces the exchange of information to inform and organise all the agents currently active. For the exchange of Midi-messages more direct connections are being used instead of multicast as shown in Figure 2, which gives an abstract view of the connections between agents in the framework.

ADRI is not based on some existing multi-agent architectures, because of real-time performance issues during the play, to reduce the overhead in the exchange of messages. Other non-specialised communication protocols give more overhead in the communication which has effect on the timing of the sound. The agents are communicating with each other by sending their

messages in XML (Extensible Mark-up Language) with information, lesson-plans, notes or complete songs to a specific group of agents. If the need occurs to combine functionality with another agent platform a sort of translation agent can be added, which can act as a gateway between the two platforms.

#### 5. Using the piano environment

After creating the platform an application has to be found to specialise on a specific area. The potential users can add their knowledge to it or give their opinion now they have a framework they can work with. Having this minimal implementation of agents, the framework can be used in different situations. It can be used as multi-user environment to play music together, as an expert tool for playing the piano or for giving lessons in piano playing. Below some of these applications are briefly described.

In the basic environment the piano can be used as an instrument on which one or more people can play. Songs can be recorded, saved, opened and played visually by showing which keys and notes are played. A good aid for advanced players could be the tool to analyse songs or chords by transposing songs in a higher key or chord recognition. But also for the beginner the environment can be helpful, because the keys on the 3D piano can be coloured to show which key produces a certain sound.

As a teaching environment the system can offer different ways of guiding a student, providing feedback on his play or it can be an administrative tool for piano teachers. A teacher can set the system to monitor and evaluate the student when doing his homework. At first a real teacher will be intensively involved using the system.

After a while and some more research, the role of the agents can be much bigger when they teach themselves how to proceed with the lessons and how to keep the individual students motivated in their play.

## 6. Future work

Tools have to be developed for the teacher to add more knowledge to the right agents and give them the possibility to evaluate the students and, more importantly, the system itself. But also users that can already play the piano can provide useful suggestions. They can already use the system to play together remotely and visualise songs in different scales on the staves.

More functionality can easily be added to the system, by adding specialised agents to the platform without changing the basic existing structure. Adding an agent that is able to convert the dialogue to speech acts, makes the system capable of giving feedback to the student without him having to read the text output.

A data-glove can be added as an input device so the physical movements of the hand can be used as input in the virtual world. An agent can translate those movements into useful messages and send them to any interested agents. In this case two hands have to be modelled and added to the environment, which also can be used to demonstrate to a student how to press the piano keys instead of which key is to be pressed.

Adding self-adapting agents can create the possibility for the system to learn from own experiences with students. Not only agents but also other tools that are useful in the piano-education can be added such as different visualisations of music or something simple like a metronome. Besides adding functionality the knowledge used in the lessons has to be extended and added, preferably using a standardised representation.

Although there has been done no scientific testing or evaluation yet, several teachers were found willing to look at the technical framework to give their opinion about the practical use of it. In our opinion they could only give suggestions on the proposed system when there was some prototype to show to them. It turns out that three real piano teachers are quite enthusiastic about the proposed ideas and want to test the environment to help to develop it further to give it a practical purpose.

We conclude that the present implementation of ADRI is basic but powerful enough to prove the value of use of the system. Many ideas came forward for applications of the system but the most important aspect is that a prototype can be shown to let future users know what is possible so they can comment on it and add more domain knowledge. Existing agents can be developed further and

more agents can be added in co-operation with teachers or users.

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