Collaborative dance between robot and human

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Abstract—Dance is an inherently embodied activity. The dancer is attuned to the effects of the physical world on her own physicality and the relationship of her presence to other dancers. This research is an investigation into artificially intelligent performing agents and robots and how a human dancer can guide the learning and performance of a robot performer. Using Artificial Neural Networks as the bases for the agent’s computational intelligence, performing agents were created that can perform by collaborating with human dancers through robots. Keywords—Dance; Machine Learning; Collaborative Performance;

I. INTRODUCTION

This paper describes research being undertaken at Motion.Lab into performing agents, particularly in the area of dance. Past research has centered on software agents, which has now expanded out into physical robots. The research has particular interest in developing environments that enable the human and non-human agents to co-create live performances. Artificial Neural Networks are used to enable movement learning from human to agent as well as interactive possibilities in performance. Performances often incorporate immersive 3D projections that are created from the dancer’s data and now also respond to the robots. The robot’s computation and movement can be derived from the 3D environment through the use of the neural networks interacting with motion capture data from the human performer.

II. RELATED WORK

Neural Networks have been used extensively for learning movement in robotics. Wang and Bai [1] used feed forward neural networks to improve the accuracy of a robotic arm. Neto et al [2] used simple controllers such as wii along with neural networks to allow gestural control of a robotic arm. Stanton et al [3] used neural networks to learn a vocabulary of movement from a human with the purpose of allowing remote tele-operation of the NAO robot so that the movements were adaptive to the robot’s morphology without a kinematic model. Ogata et al and Aucouturier et al both used neural nets, to map movement to sound, and movement to perceived rhythm [4].

Motion capture has been used for transferring movement to robots in a number of projects. The above-mentioned work by Setapen et al [5] also used motion capture to control a NAO robot, using an inverse kinematics model to map human movement to the motors. Song et al [6] used a custom wearable motion capture setup to teleoperate a robot. Matsui et al [7] used motion capture to measure both a human and robots movement and adapted the robot’s movement to be closer to the human’s in order to achieve more realistic movement in the robot.

Robotics has a long history with using dance as a means of providing a challenging test bed. In the article by Jean-Julien Aucouturier [4] Ikeuchi et al present a “Learning From Observation” (LFO) program that is able to learn movement postures from the Kabuki and Kyogen dance traditions. Ogata et al used neural networks to map sound to movement allowing a robot to learn to respond physically to auditory stimulus. Michalowski and Kozima present a novel study in rhythm whereby a robot is able to pick up the rhythmic patterns of dancing children and move in synchrony. Kosuge et al developed a ballroom dancing robot that can partner a human and take cues from the human’s lead. They use Hidden Markov Models to estimate the next step required and a motion generator model to coordinate stepping with the human input. Mataric describes a system for learning base behaviors or primitives from observation of human movement allowing humanoids to dance the Macarena [8]. Augugliaro et al developed a means of generating coordinated group choreography in quadrocopters through the use of Periodic Motion Primitives linked to detected music beat to enable a synchronized performance with the sound [9].

III. ARTISTIC FRAMEWORKS

This project developed performing agents capable of utilizing a familiar creative workflow with a dancer to engage in a collaborative performance making process. From conception, through the rehearsal process and on to
performance, the relationship between the dancer and robot is considered as a means of supporting the robot’s capabilities and learning. Allowing the dancer to support the robot throughout the development and performance process means the robot can share the dancer’s structuring abilities to augment its own. Past work with digital performing software agents has been extended to incorporate robots [10]. The software agents were trained using neural networks and could engage in performance with the dancer in a number of ways; following her movement, creating sequences based on the dancer’s current pose and recognizing and responding to the dancer’s phrases through a combination of Artificial Neural Network and Hidden Markov Model.

Related research has also investigated the use of robots as a means of transmitting a physical interpretation of movement to deaf-blind and vision-impaired audience members [11]. The small humanoid robot’s movement was based on the dancer’s movement and the robot gave an indication of the dance by guiding the audience member’s hands. This technique was based on observations of human interpreters guiding the hands of the audience member to describe movements in space. This earlier work used recorded or programmed movement of the robots based on example movement from the dancer. Later we used motion capture to enable the robot to move through an intermediary avatar in the unity game engine and in the latest iterations the neural network animates the robot again through the software avatar in the game engine.

IV. METHOD AND OUTCOMES

Movement choreographed by the dancer was motion captured and given over to the neural network for learning. We have used Motion Analysis and Optitrack optical mocap systems. The neural network (a Self-Organizing Map (SOM), [12, 13] enhanced with a temporal Synaptic layer) was run in the unity game engine so that there was a unifying platform for all the components to interact and exchange data, the projected visuals, movement, and performer locations could all interact to create the final performance. The trained neural network was then used to enable a software avatar to move by using the learned movement patterns contained in the self-organizing map to animate the software body. This avatar in turn provided the movement for the robot. The motion capture data was also the perception system of the robot, allowing it to see how the dancer was moving and providing the data to interact with the neural network to enable a number of movement capabilities for the agent – dancer relationship. The robot could recognize the dancer’s movement and respond with similar movements that it had learnt.

In earlier work with the robots, such as for providing movement experiences to visually impaired audience members, the movement was programmed or captured onto the onboard computer. In later work the robot combined on-board and off-board computation enabling the robot to share information from the 3D projected environment and dancer movement, by way of the Unity game engine, to enhance the robot’s movement. This use of distributed computation enables a lot of opportunities such as running more complex deep neural networks in future to further enable the robot’s interactive and performance capabilities. It also means the robot has an integrated relationship with the projected 3D environment including the human dancer’s data and representation.

The use of artificial neural networks to allow the robot to learn to perform is a great challenge and the use of embodied practice to enable intelligent behaviour in physical objects such as robots has great potential for artistic and robotic development.

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REFERENCES

Figure 1. Using a humanoid robot as a haptic device to convey a sense of dance movement to vision impaired audience members.

Figure 2. Dancer and humanoid robot performers.

Figure 3. The robot’s movement and dancer’s motion capture data are incorporated in a game engine and used to generate immersive projections (3 walls and floor).

Figure 4. The robot movement can be programmed, internally motion captured (recorded puppeteering), generated from live motion capture or generated from a trained neural network.

Figure 5. Robot movement enabling vision impaired audience to get a sense of the dancer’s movement.