# The hybrid Agent MARCO: A Multimodal Autonomous Robotic Chess Opponent

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*HAI 2014*, October 29–31, 2014, Tsukuba, Japan.
ACM 978-1-4503-3035-0/14/10.
http://dx.doi.org/10.1145/2658861.2658915

## Abstract
This paper introduces MARCO, a hybrid, chess playing agent equipped with a custom-built robotic arm and an emotionally expressive, virtual face presented on a small, servo-controlled display. MARCO was built to investigate the hypothesis that hybrid systems capable of displaying emotions make playing chess more personal and enjoyable. In addition, it is our aim to realize emotional contagion between man and machine in that the agent has the power to influence the human player on an emotional level and vice versa. The hardware components consist of eight Dynamixel servos, an Arduino-based control board, a 5.6 inch display, and a DGT chessboard. The software components run concurrently as separate processes. The main components are the virtual agent framework MARC, the WASABI Affect Simulation architecture, and the TSCP chess engine.

## ACM Classification Keywords
I.2.9 [Computing Methodologies]: Artificial Intelligence—*Robotics*

## General Terms
Chess, Robotics, Human-agent interaction, Hybrid agent, Affective Computing

## Introduction & Motivation

With the advent of humanoid agents—both robotic and virtual or even hybrid as presented here—chess offers a good opportunity for system evaluation. Robotics researchers find an interesting challenge for both hard- and software design in grabbing and moving chess pieces. Researchers in the fields of human-computer interaction and affective computing use chess as a situational context, which does not need to be explained to most people letting them instantly dive into the interactive experience. Questions such as how different embodiments might change player satisfaction and how the integration of a virtual agent expressing emotions influences a human's stance towards a computer system have recently been investigated [8].

MARCO features a low-cost robotic arm to autonomously move chess pieces. A custom built, small sized, robotic display presents a highly anthropomorphic virtual agent's head to realize a hybrid embodiment. Its modular software architecture relies on an established emotion simulation architecture as one of its core modules.

We aim to address the following research questions: (1) Is it more enjoyable to play against MARCO (i.e. the robotic arm with the virtual agent) when the agent expresses emotions as compared to when it remains equally active but emotionally neutral? (2) How contagious is the agent on the emotional level and which behavioral factors are best suited to maximize emotional contagion?

Additionally, MARCO allows us to tackle systematically the general question of how and when "mindfulness" is ascribed to machines [9]: (3) Is the most human-like and emotional agent evaluated as more (socially) intelligent than its less complex/human-like versions?

The remainder of the paper is structured as follows. First, we explain how the employed chess engine evaluates board positions. Subsequently, MARCO's hardware components are detailed, before its software components are described. The paper is summarized by presenting our ideas for future research.

## Hardware description

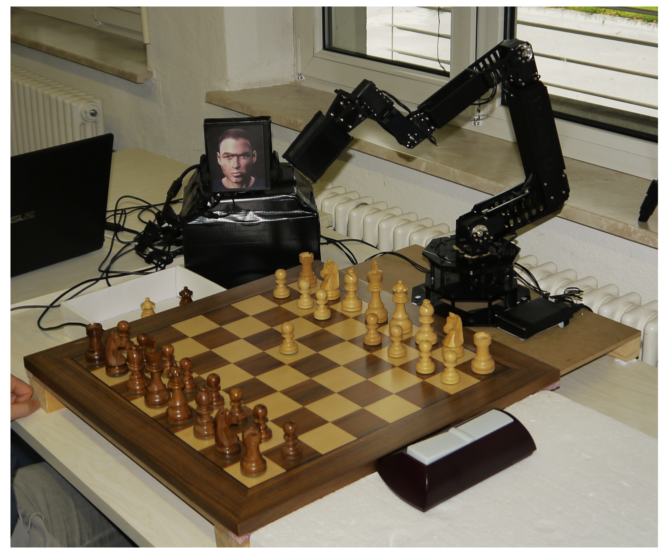

**Figure 1:** The pan-tilt-roll agent display, the robotic arm, and the digital chess board with the chess clock after MARCO performed its opening move. The laptop in the back is running MARCO's software modules and the small black box next to the robotic arm contains the Arduino components. A Kinect sensor for human player tracking is mounted on a tripod behind the robotic arm (not visible in this picture).

The complete setup is presented in Figure 1. It comprises a pan-tilt-roll display with the virtual agent's face, a robotic arm, and a digital chess board with a chess clock.

The design of the robot's arm is based on the "WidowX Robotic Arm Kit Mark II" [1] available from Trossen Robotics. The rotational base remained unchanged, but the arm itself needed to be extended and the gripper modified. The custom extensions for the arm were printed with a 3D printer. Five Dynamixel servos of four different families move the robot's arm. For the base and wrist two MX-28 servos are used. An MX-64 servo moves the robot's elbow and an MX-106 servo its shoulder. The gripper is opened and closed by an AX-12A servo. With a maximum reach of $550mm$ the robotic arm can reach all 64 squares of the $480mm \times 480mm$ DGT tournament chess board.

The pan-tilt-roll display component features a 5.6 inch upright TFT LCD display with a physical resolution of $640 \times 480$ pixels at 16bit color depth. It is positioned to the left of the robotic arm to give the impression that these two components belong together and it is mounted high enough that the virtual agent could potentially overlook the complete chess board. Three Dynamixel AX-12A servos are connected to the same Arduino-based control board as the robotic arm to change the display orientation during the game along all three axes.

The DGT chess board is a wooden board with standard Staunton pieces and $55mm \times 55mm$ squares. Each piece is equipped with a unique RFID chip that makes it recognizable. The board is connected to the computer with a USB cable, and it transmits the position in FEN format to the engine every time a change is performed.

## Software description

Except for the external MARC framework, the complete system is implemented in C++ using the Qt SDK [2] to enable cross-platform functionality. Communication with the hardware parts (i.e. the DGT chess board and the Arduino board) is realized by relaying their output to the Qt-specific event loop.

**Figure 2:** The virtual agent expressing *anger*, *neutral*, and *joy* (left to right)

The system consists of five main components which are linked together by the main module to form the chess playing agent: (1) the DGT board controller, (2) the TSCP chess engine, (3) the WASABI emotion simulation, (4) the robot arm controller, and (5) the MARC animation framework. The NovA toolkit for tracking the human player runs on a separate computer, because of its high demand of processing power.

The general design follows the one described in [4]. The main information flow originates, on the one hand, from the DGT chess board, which detects when pieces are lifted or put down. On the other hand, the chess engine reacts to a human player's moves by calculating MARCO's move in response. This is sent as movement commands to the robotic arm and, at the same time, the virtual agent receives a behavior description in the behavior markup language (BML) to respond non-verbally with eye-gaze and head movements. The latter are realized by physical movement of the display (instead of rotating the virtual representation alone).

The TSCP chess engine [7] evaluates the position using an alpha-beta algorithm based on a number of criteria like: pieces left on the board, activity of these pieces, security of the king, etc. The greater the depth the more precise is the evaluation. Apart from determining MARCO's next move, the changes in chess board evaluations over time are used to derive emotional impulses that drive MARCO's emotion dynamics inside the WASABI emotion module [5].

The virtual agent is animated by the MARC framework [6] and displayed on the 5.6 inch pan-tilt-roll display next to the robotic arm. Emotional facial expressions (see Fig. 2 for examples) are triggered by WASABI and are combined with text-to-speech synthesis provided by OpenMARY inside the MARC framework to create lip-sync animations of emotional verbal utterances.

For tracking and analysis of the human players' nonverbal behaviors during gameplay the "NovA - Nonverbal Behavior Analyzer" is integrated into our setup [3]. In combination with the Microsoft Kinect sensor this framework allows for the automatic detection, recording, and offline analysis of head orientation and body posture.

## Summary

This paper introduced MARCO, a chess playing hybrid agent equipped with a robotic arm and a screen displaying a virtual agent capable of emotional facial expressions. The system can play chess autonomously against a human player, whose non-verbal behavior is recorded for later analysis.

This combination of hard- and software components allows us to empirically investigate next, which factors support emotional contagion between artificial agents and humans. We speculate that a human player's enjoyment will increase together with higher levels of emotional contagion.

## References


[1] http://www.trossenrobotics.com/widowxrobotarm.

[2] Qt: Cross-platform application and UI framework. http://qt-project.org/, 2014.

[3] Baur, T., Damian, I., Lingenfelser, F., Wagner, J., and André, E. Nova: Automated analysis of nonverbal signals in social interactions. In *Human Behavior Understanding*, vol. 8212 of *LNCS* (2013), 160–171.

[4] Becker-Asano, C., Stahl, P., Ragni, M., Martin, J.-C., Courgeon, M., and Nebel, B. An affective virtual agent providing embodied feedback in the paired associate task: system design and evaluation. In *Intelligent Virtual Agents (IVA 2013)* (2013), 406–415.

[5] Becker-Asano, C., and Wachsmuth, I. Affective computing with primary and secondary emotions in a virtual human. *Autonomous Agents and Multi-Agent Systems 20*, 1 (2010), 32–49.

[6] Courgeon, M., Martin, J.-C., and Jacquemin, C. MARC: a Multimodal Affective and Reactive Character. In *Proc. 1st Workshop on AFFective Interaction in Natural Environments* (2008).

[7] Kerrigan, T. Tom kerrigan's simple chess program. http://www.tckerrigan.com/Chess/TSCP.

[8] Leite, I., Martinho, C., Pereira, A., and Paiva, A. icat: an affective game buddy based on anticipatory mechanisms. In *Autonomous agents and multiagent systems*, AAMAS '08 (2008), 1229–1232.

[9] Nass, C., and Moon, Y. Machines and mindlessness: Social responses to computers. *Journal of Social Issues 56*, 1 (2000), 81–103.