How to Make People Think You're Thinking if You're a Drawing Robot: Expressing Emotions Through the Motions of Writing

Avital Dell'Ariccia
Mechanical Engineering
Technion
Haifa, Israel
avital.de@campus.technion.ac.il

Alexandra Bremers
Information Science
Cornell Tech
New York, NY
awb227@cornell.edu

Johan Michalove
Information Science
Cornell University
Ithaca, NY
jam844@cornell.edu

Wendy Ju
Information Science
Cornell Tech
New York, NY
wendyju@cornell.edu

***Abstract*—We developed a system to explore expressiveness for a robot playing Tic-Tac-Toe against a human. Our robot is based around a pen plotter which performs expressions through the modalities of motion and drawing, aiming to enhance the social engagement of the human-robot interaction.**

[500]Human-centered computing Empirical studies in HCI

***Index Terms*—Tic-Tac-Toe, pen plotter, human-robot interaction**

I. Using motion to communicate emotions and thought in robots

Motion cues can reveal details on a person's physical and mental state and are an integral element of social communication [2]. Communication using a robot's locomotion path is easy to understand, and potentially useful for interacting in 'playful' situations [1]. Quantitative parameters to describe movements can be matched to a specific emotional state [9]. A human-like robot is perceived as more positive and empathetic [4]. Many current robots, however, are appearance-constrained and unable to perform facial movement and gestures, limiting emotional expression. Seeing the benefits of expressive behaviors in robots other simple, yet intuitive modalities for expression need to be explored [3].

A. Why should robots show thoughts?

Emotions can be a way to communicate the robot's internal state, providing users with access to the robot's intentions [5]. Robot behaviors which are readable improve interaction, if they allow people to understand a robot's current and next actions [6]. To reach a higher level of autonomy, robots need to behave such that humans understand it [9].

B. Does apparent "thinking" improve robots' performance?

It makes pragmatic sense for robots to remain still while planning movements [6]. However, the success of a robotic platform depends on more than task performance [2]. People display a greater social engagement and make greater attributions of mental state when playing against a robot presenting human behaviors, thinking the robot wants to win (as humans would do) [7]. Showing forethought improves a robot's readability, appeal and approachability.

II. Our contribution

We developed a set of expressive behaviors for a Tic-Tac-Toe robot. Our robot consists of a computer, running Python and OpenCV; a camera and AxiDraw pen plotter [8]. An additional camera is used to record the robot expressive movements shown in the video (Figures (1a) and (1b)).

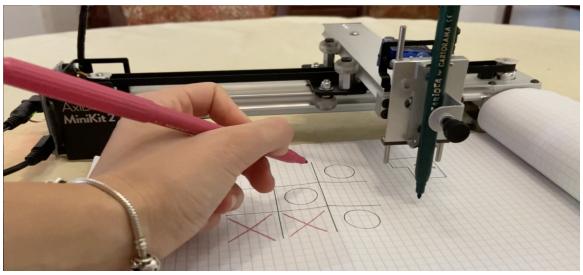
We hypothesize that people playing against a robot show different reactions than playing against a human, as the players do not develop feelings towards the robot [8]. We explore if expressive behaviors through writing and drawing motions could cause players to attribute emotions, desires and mental states to the robot, thinking that it *wants* to win. Pen plotters have the essential capability of making marks on paper - we thus design expressive behaviors not only through motion, but also ithrough drawing and writing.

III. Parameters in robot's motion

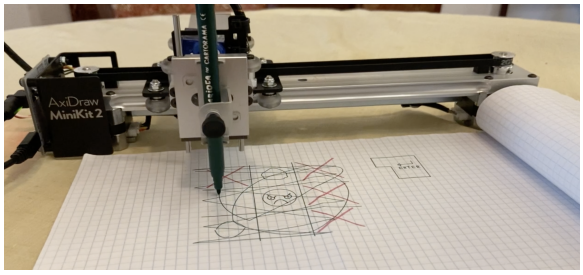
We watched several people playing a game of Tic-Tac-Toe and observed their behaviour and movements while playing, combining this information with literature insights [1], [3], [6]–[8]. We analyzed quantitative parameters that could be linked to feelings. This concept is also at the base of the Laban Movement Analysis [9] which connects velocity, acceleration and curvature to emotions as happiness, anger, sadness. Table 1 describes the final movements. Our main considerations were:

- *The pacing of a "thought"*: emotions are generated by the robot's goals and expressions demonstrate the robot's progress toward its goal, rendering the timing of the body language crucial. To give the robot the appearance of thought, it needs to show expressive movement just before it performs the task. This operation adds time to the performance, but makes the robot appear as it is thinking about the task before it performs it [6].
- *Indirect movements*: the robot wanders around more while moving towards its next goal, to appear as if it is "looking for something" [1].
- *Quick movements*: the robot moves to the next goal in a hurry, with urgent movements that are less time-consuming. This expresses happiness and enthusiasm [1].

Fig. 1: Our motions were implemented in a Tic-Tac-Toe robot.



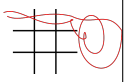
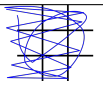
(a) Playing against a Tic-Tac-Toe robot. The Tic-Tac-Toe game has already started. Both the human player and the plotter are positioned on the grid ready to write, highlighting a more interactive game-play.



(b) The robot expressing anger when it loses. The game has finished, the human player has presumably won. The plotter is scribbling all over the grid in a clearly frustrated way.

- *Higher acceleration*: this is usually interpreted as stress and aggression.
- It is easier to express negative emotions rather than positive ones [6].

TABLE I: Expressive movements shown in video. (Lines in red indicate pen up, lines in blue, or "pen down" label indicate marks on paper).

Movement	**Characteristics**	**SVG file**	**Pen down**
Slowly wandering around grid before writing.	Indirect movements and low speed.		No
Confident, fast, no wandering.	Direct movement and high speed, urgent, pen down.		Yes
Quickly wandering around whole paper during opponent's turn to distract.	Indirect movements and high speed.		No
Slowly moving around a few places.	Semi-direct movements and slow speed.		No
Slow, roaming around same place repetitively.	Indirect movement and low speed.		No
Not confident, shivering while writing.	Slow movement, semi-direct, pen down.		Yes
"Cheating", attempt to write where the opponent's move is already present.	Indirect, high velocity, high acceleration, pen down.		No
Mad, scribbling all over the place, chaotic motion.	Indirect, high speed, high acceleration, pen down.		Yes
Happy, moves around to celebrate.	Indirect, high speed.		No
Furious, draws angry emoji on grid.	Direct, high speed, high acceleration, pen down.		Yes
Cheerful, cocky, draws happy emoji in winning place.	Direct, high speed, pen down.		Yes

These are our first steps to explore the potential of expressing emotions and thought in robots through the modality of motions of drawing and writing. We plan to carry out a user study in order to test and analyze the effects that these expressive movements have on human-robot interaction.

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