Towards a HRI System for Co-creative Drawing

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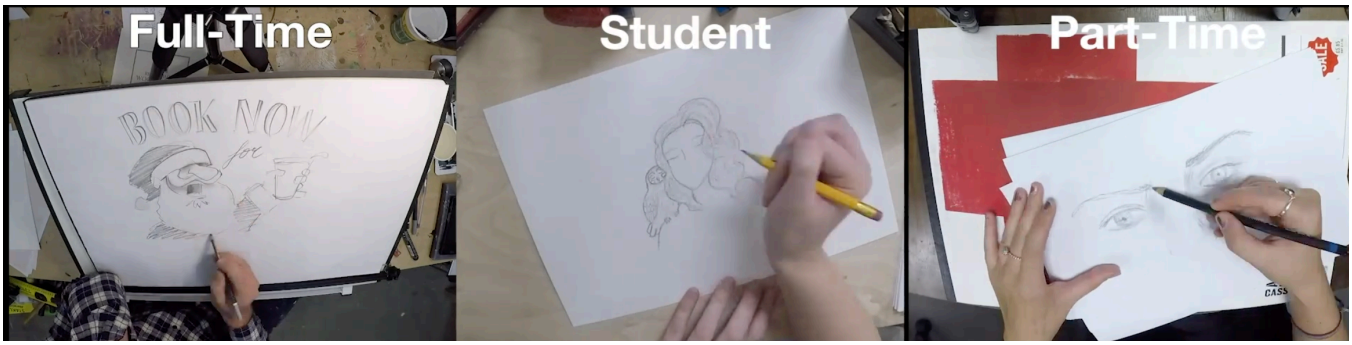

Figure 1: Drawing exercise example from a Preliminary User Study for Co-creative drawing system. Comparing three drawing participant types: full-time professionals, full-time drawing students and part-time drawing enthusiasts

ABSTRACT

This paper describes research into the development of a human-robot drawing system which aims to utilise a co-creative Artificial Intelligence (AI). Based on a pilot user study to survey the drawing practices of artists, various interaction factors have been identified that define example roles the AI might take as a co-creative drawing partner. As part of the research we have constructed a research prototype system which observes an artist drawing with physical media (e.g. pen and ink) on paper through the use of a drawing tablet and multiple cameras. The AI will maintain a model of the artist's drawing process and responds through projected visual interactions upon the drawn surface. We have outlined criteria for functional evaluation of the system along with user studies to explore the broad research question: how might the identified roles for an AI impact co-creation between an artist and a robot?

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Collaborative interaction**; • **Computing methodologies** → **Vision for robotics**.

KEYWORDS

co-creative, drawing systems, human-robotic interaction

HRI '20, March 23, 2020, Cambridge, UK

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00

ACM Reference Format:
Chipp Jansen and Elizabeth I. Sklar. 2020. Towards a HRI System for Co-creative Drawing. In *Proceedings of HRI 2020 Workshop on Exploring Creative Content in Social Robotics (HRI '20).* ACM, New York, NY, USA, 4 pages.

1 INTRODUCTION

The motivation behind our research is to create a cooperative content creation system between an artist and a machine. Currently, drawing has a large digital tools economy, and the primary workflow for artists to create 2-D content is a digital workflow. Inspired by advances in creative AI and human-robot collaborative drawing [2], we envision a system in which physical media and non-obtrusive interactions between an artist contribute to a co-creative mixed digital-physical workflow.

As a human-robotic interaction (HRI) system, we use the term "robot" to refer to an intelligent, autonomous system that has the ability to combine active and passive sensing with sophisticated data analysis and active response, designed to help artists move forward in their creative process.

This research involves examination from two perspectives:

(1) what is technically feasible through the development and evaluation of a research prototype of a real-time co-creative drawing system; and (2) what artists want with respect to a co-creative drawing partner.

In this paper, we describe our research into developing a prototype research system and, through a pilot user study involving drawing practitioners, what are some pertinent factors in defining a co-creative drawing AI, and what roles that AI might take in the co-creative human-robot drawing process.

2 RELATED WORK

Traditionally, human-robotic collaboration in the visual arts consisted of artists programming robots to draw imperatively such as AARON [8], or portraiture style through observation from an artist robot, such as PAUL [10].

Collaborative human-robotic drawing is structured around how a robot collaborates with a human. In the DOUG system [2], the robot mimics what the human is drawing and the human responds to what the robot is drawing in a simultaneous form of collaborative sketching [9]. Research into socially assistive robotics for art therapy has the robot responding to what a human is painting through contributing painting which is a visual metaphor according to a sensed emotional model [3].

In a similar approach, but outside of robotics in the creative computing area, research into co-creative sketching systems involves using visual metaphors to avoid design fixation by presenting imagery that would provide a conceptual shift in what the artist is drawing [6].

The *sketch-based* interaction research provides models of real-time drawing support, such as idealised geometric models [1], processed gradients of drawn images [7], graph-based representations of drawn stroke [11] and neural network representations [4].

3 PILOT USER STUDY

To inform development of our human-robot creativity system, a mixed-methods study of drawing practitioners (e.g. professional illustrators, fine artists and art students) was conducted in Autumn 2018 [5]. Our aim is to discover possible roles that technology could play in observing, modelling and potentially co-creating drawings with an artist.

A total of 21 participants representing a mix of professional illustrators, part-time drawing enthusiasts and illustration students were interviewed individually. Each participant completed a paper survey about their drawing habits and technology usages and attitudes. They completed three drawing exercises (Figure 1) which we recorded and they participated in an interview discussing their drawing habits, attitudes towards AI and envisioning potential collaboration with a drawing AI.

During the interviews, the participants revealed many purposes for their drawing: from commercial illustration, to satisfying the requirements of design school projects, to life drawing in community classes. These purposes can be grouped into three modes of drawing, which were reflected in study's three drawing exercises:

(1) still-life (observational drawing)
(2) mental image (draw a bicycle from memory)
(3) free drawing (draw anything)

An example of the drawing exercise for a single participant is shown in Figure 2.

Three key themes were identified in our pilot user study:

(1) Drawing with physical mediums is a traditional and preliminary way of creation for visual artists.
(2) Co-creative AI is preferable to didactic AI.
(3) Artists share a general discomfort towards automation of creative work.

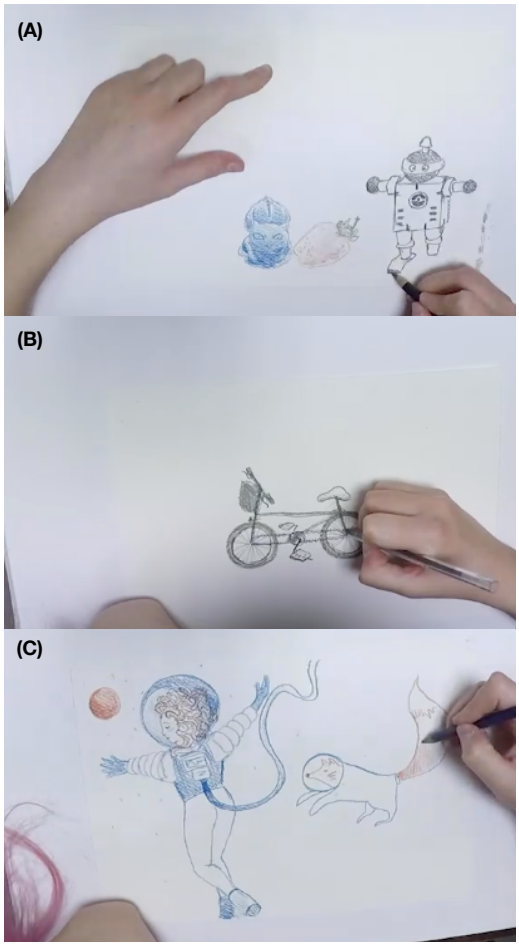

Figure 2: Drawing exercises in progress for a single study participant, showing (A) still life drawing, (B) drawing from mental image and (C) free drawing.

Discussion on these themes has been published previously [5], a more in-depth description of the preliminary user study is forthcoming.

4 MODEL OF ARTIST'S DRAWING PROCESS

We want to build a model of the artist's drawing process based on non-invasive observation of the artist at work. There are three aspects of observation that contribute to the model:

(1) Dynamics of the drawing tool (e.g. the pen movement).
(2) Presence and dynamics of the artist's body, mostly the hand holding the pen.
(3) Textural changes of the working surface, which is how the drawing evolves.

These observations produce a search-able catalog of the artist's drawing actions, as well as being a record of how the drawing evolves as a piece of art work. From these observations, a dynamic model of the artist at work is possible, in which one is able to model the presence of the artist at the piece, the anticipation of when

drawing occurs, intensity of the drawing actions themselves and to produce a measurement of engagement with the piece.

5 DRAWING INTERACTIONS

Using this model of the artist's drawing process, opportunities arise for interaction with an AI. The preliminary user study (Section 3) yielded ideas varying from concrete to lucid as to the possible roles that an AI may take as part in the drawing process for a user. The concept of an AI as creative partner was presented to the interview participants. There was a contrast made between digital word processing assistants (e.g. Microsoft's *Clippy*, the digital paperclip from the 1990's) versus an improvisational accompanist in a jazz outfit. While for musicians a clear precedent exists for collaboration in the form of "jamming" together, in visual arts it is not so clear.

5.1 Interaction Factors

From this, we developed a set of factors as to how an AI might interact during the artist process. They are:

(1) **Suggestiveness** An AI might *suggest* to the user what to draw next based on it's model of the artist's drawing process. Alternatively, the AI might draw according to its own drawing process without the goal of suggesting anything to the artist.
(2) **Synchrony** *Synchronous* drawing means that the artist and the AI are taking turns drawing onto the piece. *Asynchronous* drawing is where the artist and the AI draw independently of each other. In this case, the AI and the artist may draw with varying initiative.
(3) **Approval** What editorial control does the artist have over the AI's interaction? An AI might ask for an artist's *approval* on the content that it contributes to the drawing.
(4) **Visibility** Can the artist and the AI observe each other's drawing?
(5) **Spatial overlay** Are the artist and the AI both drawing on the same area or is the drawing occurring separately from each other?

5.2 Roles

With these factors, we can characterise a few roles, summarised in Table 1, that the AI might take with regard to interacting with the artists. An AI which operates like Microsoft's *Clippy* digital assistant, would suggest something for the artist to draw, and the artist approves or rejects the suggestion. Instead of seeking approval, the AI could be continually suggesting something to draw, in the manner of the *auto-complete* predictive text interactions. Non-suggestive roles the AI could take would be in the manner of the parlor game, *Exquisite Corpse*, in which participants take turns to contribute to a drawing without visible knowledge of what the other person is drawing, producing a novel surrealist outcome. In a more asynchronous role, the AI might be like an *improvisational* partner contributing to a drawing according to it's own model of drawing process.

From these roles we aim to explore the broad research question: how do different roles impact co-creation between an artist and an AI?

6 RESEARCH PROTOTYPE

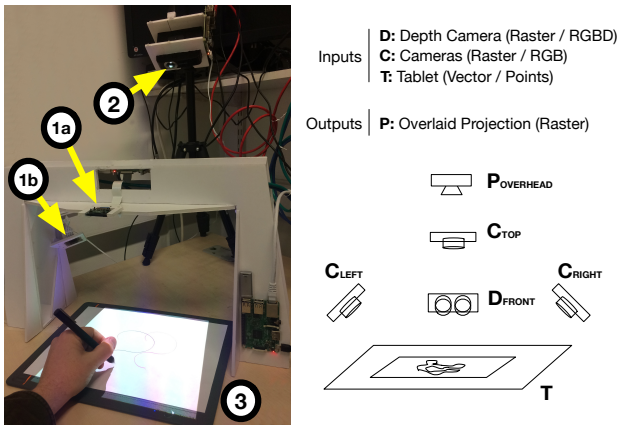

Figure 3: *(left)* Early partial prototype research system with Raspberry PI cameras (1), pico projector displaying AI Interaction (2) and WACOM Bamboo Slate digital "sketchpad" (3), each with a dedicated Raspberry PI 3 (RPI) communicating via ROS (http://ros.org).
***(right)* Schematic for current prototype system.**

Figure 3 shows an early partial prototype system (*left*) and a schematic layout of its components. It consists of a *digital "sketchpad"* (**(3)**/**T**), which uses a pressure sensitive pen that tracks movement and produces marks on physical paper. This mixture of being able to use pen and ink on paper with a digital tablet allows the artist to still draw physically (a common theme from the pilot study (([5]))) while also gathering a vector-based "ground truth" data set for model training purposes. For future versions of the research system, the aim is to rely solely on a Computer Vision system for drawing observation without a digital tablet.

Three cameras (**(1a)**/$\mathbf{C_{TOP}}$, **(1b)**/$\mathbf{C_{LEFT}}$ and $\mathbf{C_{RIGHT}}$) observe the drawing area at multiple angles and capture the textural aspects of the drawing surface. A depth sensor ($\mathbf{D_{FRONT}}$) is used to more accurately understand the physical dynamics of the drawing scene such as the motion of the artist's drawing hand in vicinity of the drawing surface. Finally, in order to interact with the drawing practitioner, the AI's drawing is overlaid on the drawing surface with a projector system (**(2)**/$\mathbf{P_{OVERHEAD}}$). Through the use of projection, the artist has the sole physical agency to manipulate the drawing in progress. Currently, our research prototype is capable of recording an artist's drawing process in a real-time manner, with adding active co-creative interactions planned as part of the research.

We have identified a set of criteria to evaluate the functional performance of the research prototype as a real-time drawing system:

- **Responsiveness** How lively is the system? What is the latency in the drawing response to the system and with regard to the projected response onto the tablet's drawing area?
- **Real-time Processing Time** Related to responsiveness, the system will have an time in which it can process something and respond to the user. How much time does the system

Table 1: Example Roles AI can take in Co-creative Drawing Workflows

Role	Suggestiveness	Synchronous	Approval	Visibility	Spatial overlay
Clippy	suggestive	synchronous	approval	visible	no overlay
Auto-complete	suggestive	asynchronous	no approval	visible	overlay
Exquisite Corpse	not suggestive	synchronous	no approval	hidden	no overlay
Improvisation	not suggestive	asynchronous	no approval	visible	overlay

have to process input and render an output to maintain a lively feedback look? Are there compromises that one can make in the interaction design in order to provide the system deeper processing time?

- **Temporal Resolution** How incremental can the progress of the drawing process be captured by the system? What are the data-capture frequencies for the input components? How does different frequencies relate to each other, and how stable are they in long-running operation?
- **Spatial Resolution** At what spatial resolution are the details of the drawing process captured?
- **Resilience** Individual components will experience noise and disruption as part of their input process. For example, the cameras, depth sensor and projector will experience *occlusion* of the drawing activity by the artist's body and by other objects placed on the drawing surface. Lighting conditions impact the quality of image capture through shadows, flickering from light sources and reflections off the artist's body. How does the system stand-up to these conditions?
- **Endurance** In the pilot user study, most artists drew for more than 1 hour. Can the research system maintain the throughput and maintain the volume of data from a typical drawing session?

7 NEXT STEPS

7.1 Data Gathering Study

Recently, we conducted a second study to gather data from a small set ($n = 13$) of full-time drawing practitioners. Our aim is to observe their drawing process through the use of our current research prototype operating in a passive data gathering mode. The participants took part in two types of drawing exercises: (1) observational drawing of a small still life and (2) free drawing from imagination. Data gathered from the participants will be used to experiment and train our co-creative drawing AI. In addition, we will informally evaluate the participants reaction to the usability of our research prototype.

7.2 Modelling of Drawing Behaviours and Drawing AI

With the data from the data gathering study, we are modelling the drawing behaviour of the drawing practitioners and exploring different ways a drawing AI can co-create with an artist. This exploratory step to construct our proposed co-creative drawing AI will be embodied in a robotic system that draws with a human artist.

7.3 Co-creative Interaction Study

Finally, we aim to experiment with our co-creative drawing AI based on the potential roles discussed in Section 5.2. Our AI will be evaluated in a larger user study ($n = 30$), with the focus being on measuring impacts of the AI on the artist's drawing process, through both objective measures (extracted from drawing observation data) and subjective self-reported means.

8 SUMMARY

In this paper, we have discussed our research investigating how a robot can contribute to an artist's drawing process. We have developed a set of interaction factors that describe example roles a robot may inhabit to take part in the co-creative drawing process. We have constructed a research prototype which is capable of observing the drawing workflow and identified functional evaluation criteria to measure it by. We have recently conducted a second user study to gather observational data from drawing practitioners and will conduct a third evaluation to assess our research through a larger co-creative interaction study. Finally, we envision the development of the research prototype to become a usable human-robot co-creative tool which will produce artistic output and be showcased within the creative computing community.

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