Robot-Human Agreements and Financial Transactions Enabled by a Blockchain and Smart Contracts

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ABSTRACT

This paper explores the design of a robot and interaction model that enables a robot to engage in human-like financial transactions, and to enter into agreements with a human counterpart. More explicitly, (1) we bestow the agent with a cryptocurrency wallet and (2) define bilateral and multilateral agreements that can be automated as smart contracts in a distributed ledger. As a use case of a robot with such features, we describe roBU - a traveling robot, that can enter into financial agreements in exchange for assistance in traveling the world. With this effort, we expect to validate the idea of near-future scenarios where autonomous or semi-autonomous agents are endowed with, a type of, social autonomy and the ability to engage in financial transactions. We believe the latter can improve task completion and enable further exploration of robot-human relationships and dependencies. All this, with the end goal of establishing mutual trust.

1 INTRODUCTION

Trust is an important factor that influences the interaction and reliance on an agent [1, 7]. Consequently, as we look into the future of automation, there's a dire need to design agents that support interdependence and coactivity [5]. Trust, interdependence and coactivity are highly related concepts that revolve around an actor's willingness to be vulnerable and accept the risk of transacting with another [3]. In hand with the vision that one day agents can faithfully jointly interact with humans, and with the understanding that this will lead to more productive outcomes for both the agent and the human - we explore a means of allowing robot agents to enter into agreements with humans via smart contracts - digital agreements which can embody complex contractual relationships in code, are self-executable, self-enforceable and self-verifiable [6, 9].

A social robot with such capability brings a paradigm shift to the set of possible interactions, allowing both a robot and a human to engage in promises or mutual exchanges of value.

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The automated enforceability of such agreements, also enhances the notion of machine agency - enabling the robot to bestow functional trust on a human and to more efficiently exercise proxy agency or socially mediated agency. In our use case, we leverage cryptocurrencies and smart contracts to enable productive economic exchanges of value. A robot can propose an activity in which it requires assistance, define a set of clauses or conditions, penalties and define an economic reward in a cryptocurrency like Bitcoin or Ether [4, 8].

These smart contracts are, in essence, data-driven agreements with hard guarantees and zero ambiguity. In the case of our traveling robot, roBU can simply generate a smart contract that states its current geographical location, a goal location, and the price it is willing to pay for someone to take it there. roBU can then monitor and publish state information, such as its geolocation. If certain conditions are met, such as arriving at the goal destination, the smart contract can trigger the automated release of funds to the designated party in the contract. The blockchain serves as a means to immutably record transactions and as a backbone for these smart contracts.

More complex agreements, which leverage various data sources, can be drafted to further enable transparent collaborative interactions between a human and a robot.

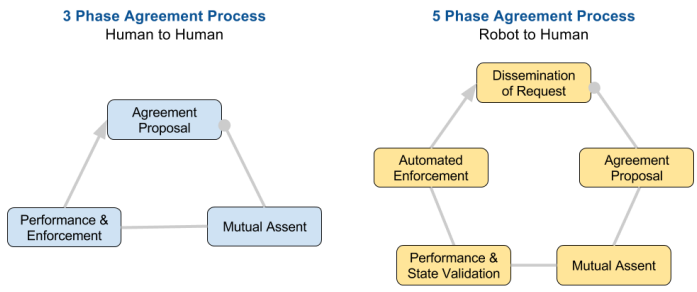

Figure 1: Phases of an agreement

2 DESIGN AND DEVELOPMENT

We developed roBU, a traveling robot, as a use case for an agent that is required to enter into mutually beneficial agreements with humans. Its end goal is to travel the world. The morphology of roBU is adequate to allow it to fit in airplanes' overhead compartments, a car seat, or to simply be carried on a person's lap. The robot's backpack holds accessories necessary to allow the

robot to function, i.e. battery charger or other items fellow humans might share.

The key technical requirements for roBU to leverage a blockchain and smart contracts are (1) access to the internet, (2) a screen to communicate, display tasks as well as natural language agreements, and (3) input sensors including a camera used to scan a wallet address and to collect visual data. Additional sensors such as IMU's and temperature sensors can be leveraged to allow more complex agreements to take place.

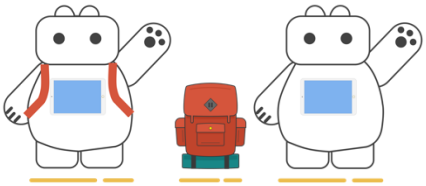

Figure 2: Design of first prototype - roBU

The interaction diagram is shown in Figure 3. The agent encompasses: the physical robot, the application that connects to the smart contract and the robot's cryptocurrency wallet. A human can enter into an agreement with roBU by first selecting an activity on screen and agreeing to the terms and conditions. Due to the financial nature of the transaction - we can either simply request the human to scan his or her wallet address, represented as a QR-code, to define where the funds shall be transferred, or employ a digital signature scheme. The application can then communicate with the smart contract and indicate the start of the agreement. roBU then continuously updates its state information. The state information is leveraged by the smart contract which can trigger any contractual logic such as the release of funds. A release of funds, in this context, means the smart contract's automated execution of a cryptocurrency transaction to either the human or the robot's digital wallet.

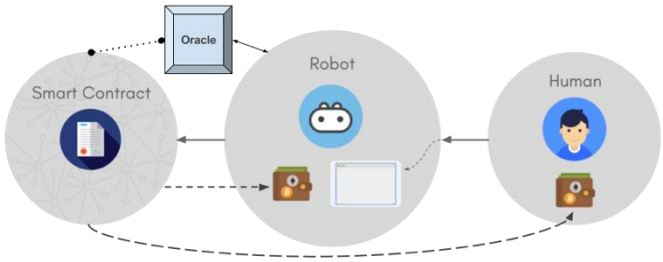

Figure 2: Interaction diagram

The first iteration of the software leverages Ethereum and a software oracle that processes roBU's state information along with other real-world information. Due to the decentralized and trustless nature of a public blockchain like Ethereum's, an oracle must be used as a means to access or publish data off-chain in a secure and trusted manner [10]. The second and current iteration explores the use the Accord Project's template protocol to create natural language agreements that can be explicitly bounded by business logic, as well as the use of permissioned blockchains [2].

3 DISCUSSION AND FUTURE WORK

We successfully performed a localized on-campus test of roBU in which the tasks were simply to help roBU attend a predetermined list of classes. We predefined these agreement, and allowed roBU to tweet images, which were then used to allow public voting to assert its true location. This information was then leverage by the smart contract to trigger the fulfillment of the agreement. The next steps of our research are aimed at preparing roBU to travel the world. This includes the development of more complex smart contracts that further leverage IoT components and the development of more sophisticated oracles.

Present considerations fall into three categories: (1) systemic, (2) software and (3) mechatronic. As in any system that involves trust and the exchange of value, it is expected that malicious actors will emerge. Legal and liability considerations need to be made over the fulfillment of agreements between the agent and a human, i.e. in the case were the robot fails to make a payment due to technical failures. Congruently, more robust software and hardware is under development to enable roBU to travel the world and withstand different environments. The morphology of the robot is crucial to enable efficient interaction between the agent and a human. We purposely employ a minimalistic modular design to allow the evolution of the robot. This is both in terms of the hardware and software. For example, in one scenario, the public can propose the creation of an agreement that requires roBU's arms to be upgraded in functionality. The latter agreement can be funded as well as monitored by the public.

Game theoretical scenarios are discussed on a separate paper. These scenarios relate explicitly to human-agent interaction, socio economic considerations and trust from an economic perspective. Further updates can be found in roBU's homepage [11].

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