Research Statement

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The core message in the statements below is that (in my research) the **new generation of AI** methods has to be based on dynamic/flexible learning methods which can only be provided by the **social robotics** approach in which learning is done via continuous interaction between *human trainers* and *robotic trainees*. Many existing systems (like *chatbots* in a recent project) are based on **inflexible structures** (decision trees in chatbots) and are difficult to generalize. My latest research shows that social robotics is not limited to hardware systems but can also be applied to *software automation*, with slightly different components. In both hardware and software applications, the key point is to create a robust **training interface** between humans and robots. As a recent hardware example, I have had success with a man-machine interface based solely on accelerometer feedback on commodity smartphones.

I. My Past and Present Research

My current research is seemingly a soup of topics describes below. For me, the various ingredients in the soup are the components of the research I refer to as **Cloud AI**. However, another facet to the same combination is a new generation of **human-AI hybrid systems**. In recent years, I have experimented with *social robotics* [1] and even created a new kind of **software automation** powered by the new Metromap Classifier (MC) [2]. Social robotics heavily depends on reliable feedback between human trainers and robot trainees. In hardware, this part creates difficulties because it involves vision – a robot has to *see* and *recognize* visual (rarely audio) signals made by the trainer. My current prototypes explore simpler and more reliable communication channels. For example, in a prototype that needs to learn a given **person's gait** on the fly (zero hardcoding), I use G-sensors on commodity smartphones as both motion sensors and for human feedback – the human can stroke the smartphone in a certain way to indicate that the robot has made a mistake. The obvious future applications for this technology is the various forms of exoskeletons – in Japan this research goes under the name of *power assist*.

The soup of topics incorporated into this overall research is as follows.

Total Cloudification is a technology that makes true *federated* and *fog clouds* possible in reality. I have a patent on the platform that implements the *Local Hardware Awareness* (LHA [la:]) feature [3] – the key necessity for cloudifying the various resources both at network as well as at network edge. IoT/IoE devices and robots live at network edge are are expected to be part of *fog clouds* in near future. Prototype *fog cloud boxes* are discussed in [4]. Making wireless devices part of the fog cloud requires another new technology – this is another platform recently patented by me [5]. These two patents extend the reach of federated/fog clouds into the wireless parts of network edge. The two main benefits in the cloudified world are *(1)* being able to collect BigData from network edge easier and *(2)* being able to deploy software from core to edge using migration.

Big Data is easier to collect in the cloudified world. But the new generation of Big Data processors needs to *produce results in realtime*. My recent research formulates the **Big Data Replay** [7] method which does just that – it uses *data streaming* for rigid statistical processing of a portion of time-aligned data bulk that is replayed in realtime. Replay is done on a single machine and makes use of multiple cores – a **lockfree multicore** parallel processing method is defined in [6]. This part of my research makes sure that valuable information is promptly extracted from large unstructured data bulks with maximum efficiency.

Circuit Emulation research originally started as part of the Big Data Replay engine [8] above, but has expanded into the general topic of *bulk networking*, where the bulk can be chunks of data, migrating VMs/apps/resources, etc. The point of this technology is to create reliable *high-throughput end-to-end networking* on top of the otherwise *best-effort mode* in the global network today.

Diff Sync and Multisource Aggregation are the technologies that provide alternatives when the *circuit emulation* above is not possible. The **DiffHub** technology in [9] works by sending binary diffs (software, data, etc.) across the multiple network-distributed nodes. Multisource aggregation is the other way to boost efficiency of end-to-end networking – the method originally existed in the area of *P2P content delivery* [10] but was later extended into the **cloud-backed version** of the technology [11]. The cloud version is more suitable for the cloudified world where providers create multiple copies (caches) of the same data/software in the cloud while the client aggregates the one copy from multiple parallel downloads.

Cloud Resource Economy is what the increased complexity from the above technologies will lead to in near future. The total resources of multiple federated and fog clouds are treated as a *resource economy* powered by the new generation of billing/accounting methods evolved from the basic idea of **micropayments** [12].

Finally, **Social Robotics** is its own area in my research [1] which has both software and hardware components. On top of having created the software version of the

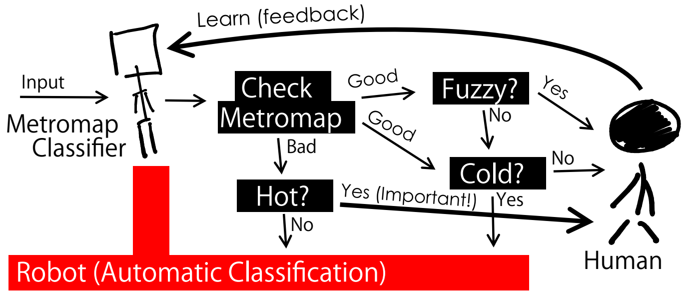

Figure 1. Example software automation design based on the *Metromap Classifier* that has both the *social robotics* and *blackswan* components.

technology – **software automation** [2], my recent papers also raised the issue of **blackswans** [13]. Blackswans are more commonly attributed to natural disasters or economic calamities, but in software and hardware robotics they are formulated as states that fall outside of the **predicted behavior** of the system. In other words, in this research the focus is shifted from the normal operation of a system to the times when the system misbehaves. In case of drones, welfare robots, autodrive in cars, etc., this is a well-recognized problem. In my research, this problem is not only recognized, but also treated.

Fig.1 shows a simple software automation design used for managing context in a knowledge base. The objective is to gradually decrease the number of times when the robot has to ask human for an advice – from the three arrows pointing to the human, it is expected that the lowest arrow (yes, important) makes up for the majority of interactions. Although this is a software-only system, the same elements and logic are used in my current hardware prototypes.

The following **representative technology** can be built from the above components. Fog clouds are used to collect data from network edge in realtime. The data grows into the Big Data at network core, where it is processed in realtime based on demands from software agents running at network edge. Federated clouds are used for development and permanent storage of AI software, which can easily migrate to network edge, again, on demand/request. Note that future services are often populations of multiple VMs/ apps separated by the network. LHAP [3] helps AI software create and maintain local resources and use multisource aggregation for fast download and diffsync for continuous update/sync duration operation. Human-AI interaction happens locally, where physical proximity to robots is highest for hardware robots. AIs migrate to a local fog cloud from network core but learn their specific skill locally using a well-defined language for interacting with humans.

This representative technology is the same for several applications found in practice today, such as *power assist* hardware robots, assigning tasks to singular drones as well as *drone populations*, etc.

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