Not the Law's First Rodeo: Towards regulating trustworthy collaborative industrial embodied autonomous systems

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ABSTRACT

Does the law stifle technology adoption? At the surface, it may appear to be that there is a regulatory gap and, therefore, such uncertainty can hinder the development and deployment of collaborative industrial embodied autonomous systems (Cobots). Cobots are a class of robots which, unlike other forms of industrial robots, have seemingly introduced new legal challenges due to the direct human-robot collaboration factor. In this paper, to shed light on the above, we investigate the gap in the applicability of the current legal frameworks to this technology from the UK and EU regulatory approaches. We argue that the current law is applicable in regulating this technology given the state of the art. We discuss implications for the regulation to enhance trust and responsible future adoption of Cobots.

CCS CONCEPTS

• **Social and professional topics → Computing / technology policy**.

KEYWORDS

Regulation, Human-Robot Collaboration, Law, Trust, Embodied Autonomous Systems, HRI, Technology, Responsible Innovation

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1 INTRODUCTION

Collaborative industrial embodied autonomous systems (Cobots) have the potential to revolutionise the manufacturing process by working alongside humans and supporting industrial tasks. Despite these promising benefits, there are various restrictions. At the surface, although robotics in manufacturing is heavily regulated, the current standards are viewed to be inappropriate to govern the implementation of Cobots given that there is not a specific regulation that govern this technology. For instance, there are strict policies on safety protocols such as physical barriers, sensors and other systems to prevent people from being in close proximity to working robots but isolating Cobots in cages defeat the purpose of this technology. The safety challenges with Cobots cannot be overcome by simply installing standard movement detection; the autonomous aspect of Cobots also requires additional safety standards for decision-making criteria programmed into robots. As Cobots learn from human workers, the system must enable robots to distinguish desirable behaviours from harmful behaviours so that a robot can only replicate the appropriate human gestures [11].

Consequently, the interactions between Cobots and humans also create the norms of endless personal data collection and processing which can face difficulty with data protection law. Moreover, technology adoption requires acceptance and trust in particular in the context of human-robot collaboration. However, there is a perceived notion that there is a lack of or uncertainty in legislation which can hinder trust and acceptance of Cobots leading to restricting the use of Cobots to their full potential in UK manufacturing. Nevertheless, this is a longstanding debate in the field of robotics and law of whether there is a lack of adequate regulation and a need for drafting new regulation specifically for robotics or whether the current regulation is adequate [27, 32].Therefore, to foster trust and deploy Cobots at scale, there needs to be greater clarity on the regulation to enforce trustworthiness of the technology. The following sections will investigate the current regulations and governance in addressing Cobot adoption challenges. The legal analysis considers frameworks and legal literature from different jurisdictions (predominantly UK and EU) given the emerging nature of regulatory development in this area. By demystifying this notion, we aim to inform policy makers, academics, and general public and discuss implications for the development of embodied autonomous systems to enhance trust and future adoption.

2 DEFINING THE COBOT

From a legal perspective, a description of the technology must be precise. However, we recognise that this rigidity is often seen as a flaw in the legal system in coping with the fluidity of the technology advancement. Therefore, before legal analysis can be conducted, we need to carefully define the technology that we are examining that demonstrates a wider scope of the subject matter. Typically, 'cobot' is a portmanteau word for collaborative robotics in manufacturing. However, most cobots were the only type of industrial robots that, by definition, was designed to operate without a physical barrier, allowing human workers to work alongside them [41]. This description does not suggest collaboration but merely co-existence in the same environment as the humans.

Studley and Winfield state that "many projects foresee robots in industry as co-workers (or 'cobots')" [58], highlighting the view

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of the future of industrial robots, a robot coworker, compared to how the term Cobot is currently used [63]. ISO refers to cobots as a robot system that shares workspace with human workers but does not necessarily collaborate with them [49]. Based on this definition collaborative robots are not necessarily designed to work with operators in the same way that human operators would collaborate with each other to accomplish a task. This description adds to the complexity of identifying collaborative robotics.

This paper explores 'Cobots' in the context of collaborative industrial embodied autonomous systems. We acknowledge the evolving meanings and discrepancies in defining cobots, emphasising that human-robot collaboration spans beyond a single type of industrial robotics.

2.1 Cobot State of the Art

Cobots are not limited to collaborative industrial robotics. When exploring the commercial state of the art of Cobots as described in this paper, we focus on the embodied autonomous systems which are designed to be safely operating alongside human workers. In the commercial space, we looked for Cobots that are specifically advertised for manufacturing or with the potential to be used in a factory. There are various companies that specialise in this type of Cobots. Table 1 below presents (non-exhaustive) examples of Cobot for different applications from both industry and academic projects.

2.2 Future of Cobots

Cobots as collaborative industrial embodied autonomous systems cover a wide range of robotic technology. The purpose of Cobots also vary depending on the design as well as level of autonomy as robot assistants, collaborative robots, and managerial robots. Currently, assistive robots appear to be more commonly discussed in the literature, but the sector is moving toward improvement in human-robot collaboration through the development of features such as body language understanding or action anticipation [36, 45, 52]. With managerial robots, Cobots can play the role of monitoring tasks performed by other robots and collaborative tasks between humans and robots [15].

Furthermore, the role of robots will likely change as the sector moves toward Industry 5.0, an industrial transition to "place the well-being of industry workers at the centre of the production process" [28, 1]. For example, with the major event of the COVID-19 pandemic, technology such as Cobots became essential to mitigate the impacts of the pandemic by performing disinfection tasks to prevent exposure to the virus [62]. In this scenario, although we have highlighted before that Cobots would likely take on more mundane tasks, a robot was taking a crucial role in maintaining a space to help prevent further outbreak of the virus. Therefore, the perception towards autonomous systems may be viewed differently as the benefits become more apparent, especially for tasks which are dangerous for humans. In this paper, we adopt an anticipatory approach in establishing a new term of collaborative industrial embodied autonomous systems to capture the wide range of industrial robots that enable human-robot collaboration.

3 REGULATORY CHALLENGES

3.1 Liability

As demonstrated above, what distinguishes Cobots from industrial robots is their ability to adapt and assist humans. Although the application of AI in robotics is becoming more prominent, the manifestation of such technology is still under high scrutiny given its “black box” computing process [44]. It is important to gain a better understanding of how technology makes certain decisions and why it takes such action. Determining liability for the AI case is a complex scenario. AI-enabled robots may have greater capabilities for decision-making and learning, making it difficult to trace the origin of an error and determine whether it comes from an improper decision of the system or is caused by the malpractice of developers, operators, or producers [64].

Consequently, it will also be challenging to make a case under negligence. In Bolam v Friern Hospital Management Committee [8], the Bolam test establishes the rule for assessing the appropriate standard of reasonable care involving skilled professionals in negligence cases which outlines that the standard required is by looking at bodies of professional opinion. The application of this test for Cobots will be difficult, given the involvement of multiple professionals and the difficulty in assessing the origin of the fault. Thus, the difficulty in arguing that developers, operators, or producers should be held responsible for a system that makes independent decisions will lead to the risk that no human will be responsible for AI action [57]. Without the reasoning for action taken by the autonomous agent, there is an underlying problem for Cobots to be unaccountable in court, posing great challenges on regulators.

3.2 Safety

Because Cobots are meant to have direct contact with humans, the guaranteed safety of Cobots must be satisfied at all times [30]. We must consider whether the safety standards that govern traditional industrial robots meet the adequate level of safety requirements required for Cobots to ensure the safety of human operators. At the time of writing, legal provisions governing the design of robots are the Machinery Directive 2006/42/EC which is implemented in the UK Supply of Machinery (Safety) Regulations 2008 and the Product Liability Directive 85/374/EEC implemented in the Consumer Protection Act 1987 (see also [48]). However, it is worth noting the potential changes of the legal provision considering the post-Brexit position of EU law in the UK. At the time of writing, the European Union Act remains in force, and post-departure CJEU case law may be used as persuasive authority in the interpretation the provisions of the Act that implement the Directive but will not be binding on the UK courts. Also, product liability and consumer protection laws apply only to domestic Cobots rather than industrial Cobots. Nevertheless, in the UK, Health and Safety at Work etc. Act 1974 and The Management of Health and Safety at Work Regulations 1999 provide general requirements for workplace safety. There is, however, no specific and legally enforceable set of rules that clearly define the safety elements required in Cobots.

Currently, the only conventional form of regulation with clear guidelines on the safety of Cobots design is the International Organisation for Standardisation, available as a guideline for Cobots safety measure through its most recent technical specification (TS 15066)

Type	Application
Robot Assistants	Osaro, AI software startup, integrated deep reinforcement learning AI software in robot, allowing it "to use visual recognition, speech, and navigation out in the real world" See link here
Robot Assistants	UC Berkeley spinoff covariant.ai (formerly Embodied Intelligence) uses AI and VR to teach robots new skills. See link here
Robot Assistants	Robotics Arm (perception training, visual and haptics): See Universal Robots, See KUKA, See ABB, See Boston Dynamics
Robot Assistants	Robotics Arm (perception training: improved haptics): See MIT soft robot, See Robo-Dumbo (robot elephant trunk, See DEXTERITY
Robot Assistants	Robotics arm (perception training: visual and sound): See CMU's Robotics Institute
Robot Assistants	Autonomous Mobile Robot (AMR): See Arculus, See MiR, See Temi, See OTTO, See Temi, See STARSHIP
Robot Assistants	Bipedal Delivery robot:
Robot Assistants	4 Legged-robot: For industrial work see SPOT, For delivery see ANYmal
Robot Assistants	Autonomous Robot Vacuum See WHIZ
Truly Collaborative Robots	SecondHands – EU Horizon 2020 project, humanoid Cobot aimed to be truly collaborative See link here

Table 1: Commercial state of the art of Cobot

[49]. ISO defines four key measures: Safety-rated monitored stop (the work stops when a worker enters the robot workspace), Hand guiding (the robot moves only under human control), Speed and separation monitoring (control the speed when a human worker approaches), Power and force limiting [53]. From a technical perspective, various research projects focus on the design and safeguards for the physical safety of Cobots, including (but not limited to) materials used for constructing the robot, system and software controlling the robot, sensors equipped in the robot [50, 54]. Some of the domains of previous prominent studies in the area of physical safety of human-robot interactions: the safety assessment and concepts of human-robot interaction in quantitative terms, the mechanical designs of robotic systems (i.e. variable stiffness in actuators) and planning and control schemes such as collision detection systems to prevent collision and reduce impact force during collisions [2, 20, 26, 31, 38, 46, 60]. Translating these actionable technical concepts into law remains a challenge.

Mental health risks are an additional safety risk that needs to be examined. The bidirectional flow of information exchange between a human and a robot worker can cause mental health safety problems due to human limitations in information processing speed [42]. Furthermore, asymmetric managerial relationships where multiple robots are assigned to a human worker can lead to increase in mental workload, leading to stress and potential errors [59].

The safety governance of Cobots must address both physical and cognitive risks, although the latter has not been mentioned much in robotics safety research.

3.3 Privacy and Cybersecurity

Privacy is becoming an increasing concern for robotics given its use of sensors, cameras, and microphones [33]. For example, managerial robots can be used as a tool for workplace surveillance. Some information captured by robots about employees can be considered as personal data and subject to data protection laws. However, this is also a question to explore in the context of ethics of what data should be collected and analysed. Consequently, it is the employer's responsibility to inform employees of this potential data collection and processing, and also robot designers and manufacturers to place safeguards in the design process to ensure user privacy is respected [7, 47]. For example, the collected data should only be kept for a limited time; therefore, such a rule should be reflected in the design [18, Article 5].

Another question to explore is whether the data should only be shared with the manufacturer to help improve the product, or should be available to employers. This led to the creation of the field of "privacy-sensitive robotics", where seven research themes were identified: data privacy; manipulation and deception; trust; blame and transparency; legal issues; domains with special privacy concerns; and privacy theory [51]. This creates a substantial road map for future research and policy direction highlighting the urgency to address data protection and privacy challenges in robotics.

4 REGULATING COBOTS

Following the challenges above, we analyse the continuous development in AI and robot regulations, including the lessons learnt from robot law and the conventional discussions on safety and liability challenges posed by autonomous systems. One of the potential answers to liability and safety challenges surrounding robots and automation points towards the use of data collected by robots, a controversial approach considered contrary to data protection principles.

In that regard, the legal analysis focuses primarily on the General Data Protection Regulations (GDPR). Additionally, in light of Health and Safety at Work etc. Act 1974, we argue that data protection must be viewed as part of an employer's obligation to ensure the safety of employees at work through adequate safeguards and relevant assessments on the use of Cobots where safety stemmed from both interaction with Cobots and the data collected by Cobots. Thus, unpacking the GDPR within the context of Cobot adoption becomes imperative. This section will attempt to provide insight how the data protection law can facilitate responsible adoption of Cobots in manufacturing.

4.1 Regulatory Gap, you say?

Robotics has been integrated into manufacturing lines since the 1950s. Recently, smart industrial robotics have been designed for the purpose of human-robot collaboration (HRC). For example, a collaborative robot designed to work next to human operators, handing over equipment and parts on an assembly line. This new generation of industrial robots would allow for a more flexible and lean process and maximisation of efficiency at work. With human-robot collaboration, the advantages are the combination of high levels of accuracy, strength, precision, speed, endurance, and repeatability of the robot and flexibility, sensitivity, creativity, and cognitive skills from the human. However, Cobots are yet to be widely adopted, and in most cases the robots are still kept in a cage, at least in the UK. So, the question is, how has the regulatory system responded to this emerging technology?

The pertinent legal frameworks concerning the regulation of Cobot adoption were elucidated. It was preliminary determined that the aforementioned frameworks are inadequate for Cobot adoption, as they neither adequately address human-robot collaboration nor provide sufficient assurance regarding safety considerations. However, in more recent developments, the European Union (EU) has recognised the need to "update" the Machinery Directive 2006/42/EC, which consequently was repealed by the introduction of Machinery Regulations (EU) 2023/1230 of the European Parliament and of the Council [19]. This revised regulation aims to harmonise the health and safety requirements for machinery, including the realm of human-robot interaction (HRI). Notably, this regulation has great potential in ensuring the safety of Cobots, and thus is favourable to Cobot adoption, as to allay concerns related to the perceived lack of regulation given the defined responsibilities and obligations imposed upon robot provider and/or manufacturer regarding the safeguarding of robotic systems in HRC scenarios.

Article 10 specifies that *"when placing machinery or a related product on the market or putting it into service, manufacturers shall ensure that it has been designed and constructed in accordance with the essential health and safety requirements set out in Annex III."* Annex III outlines the safety requirements including risks related to moving parts where HRC and HRI are addressed as in accordance to Annex III (1.3.7),

> *"The moving parts of the machinery or related product shall be designed and constructed in such a way as to prevent risks of contact which could lead to accidents or shall, where risks persist, be* ***fitted with guards or protective devices****...the prevention of risks of contact leading to hazardous situations and the psychological stress that may be caused by the interaction with the machinery shall be adapted to:(a) human-machine co-existence in a shared space without direct collaboration; (b) human-machine interaction."*

Notwithstanding the apparent possibility and adaptability in modifying guards or protective devices whilst adhering to regulatory requirement to facilitate HRC and HRI, under Annex III (1.3.8.2),

> *"Guards or protective devices designed to protect persons against the hazards generated by moving parts involved in the process shall be: (a) either fixed guards as referred to in section 1.4.2.1; or (b) interlocking movable guards as referred to in section 1.4.2.2; or (c) protective devices as referred to in section 1.4.3; or (d) a combination of the above."*

In this case, the installation of guards might counteract the intended function of Cobots, as the guards would prevent contact with the machine, thus hindering human operators from working collaboratively with the Cobots. Therefore, robot providers and/or manufacturers may resort to invoking the provision pertaining to protection devices, whereby workers can utilize wearable or similar instruments to assist in safety interaction with the machine. Consequently, ensuring safety have to be viewed from different perspectives, as mentioned above, "risks of contact leading to hazardous situations and the psychological stress." In light of these considerations, the utilisation of wearable sensors presents a viable option to support both effective and safe human-robot interaction. For instance, Al-Yacoub et al. [1, p. 651] developed "a hardware setup and support software for a set of wearable sensors and a data acquisition framework" where the data collected from the sensors can help robot identify "human physical and psychological states such as muscle fatigue, frustration and anxiety", so it can interact accordingly.

However, despite the potential solution to the use of wearable sensors to meet safety requirements, it remains plausible that the expected level of human-robot collaboration is still unachievable. In accordance to Annex III(1.4.3),

> *"Protective devices shall be designed and incorporated into the control system in such a way that: (a) moving parts cannot start up while they are within the operator's reach; (b) persons cannot reach moving parts while the parts are moving, and (c) the absence or failure of one of their components prevents starting or stops the moving parts. Protective devices shall be adjustable only by means of an intentional action."*

It is evident that the concept of a protective device still prioritises the objective of halting robot operations in close proximity to humans. Whilst Annex III (1.3.7) acknowledges the need to adapt measures in the context of HRI and HRC, it could potentially deter robot providers and/or manufacturers from producing the technologies as the prevailing requirements still pivot towards promoting physical separation between humans and robots as a means to uphold safety. Therefore, it could be challenging for robot providers and/or manufacturers to demonstrate compliance of machinery with the essential health and safety requirements in case of HRI and HRC.

The new machinery regulation has been adopted in an effort to address safety and liability concerns surrounding the rise of autonomous machinery including the uptake of human-robot collaboration, although it is still unclear as to how it defines the safety requirements to facilitate such collaborations. As the regulation is mainly directed at all machinery and not specifically to human-robot collaboration, it raises the question as to whether or not Cobots should be subject to a separate, more stringent regulation?

4.2 From Cyber Law to Cobot Law: Lessons Learnt from Easterbrook, Lessig, and Calo

Examining the role of law in regulating emerging technologies has come a long way and will continue to evolve, in particular, the debate whether (emerging) technology should be regulated under specific, separated, legal frameworks, such as 'robot law.'

This started with the introduction of cyberspace. Easterbrook [16], raised an intriguing question: Should cyberlaw be regarded as a distinct field of legal study or as a branch of traditional legal doctrines? This question arises because the legal challenges posed by cyberspace encompass various aspects of law. Easterbrook's comparison to the "law of the horse" illustrates the argument that understanding cyberspace requires an examination of its impact on a wide range of legal frameworks, and attempting to establish it as an independent domain of law further complicates matters due to incomplete comprehension of both technology and law. To quote judge and professor Frank Easterbrook, remarking on the comparison of cyber law and the Law of the Horse, noted that such area of law *"is doomed to be shallow and to miss unifying principles"* [16, p. 207].

Establishing cyberlaw as an independent domain was complicated due to the lack of in-depth understanding of both technology and law; however, this controversial debate marks the early days of technology law with an interdisciplinary research approach to unpack aspects of technology and the need to examine its impact on a wide range of legal doctrines. Over the years, researchers have worked to address the legal challenges of emerging technologies, drawing together insights from different disciplines. This approach is especially important in addressing the criticism that a regulatory gap arises from the law being far behind technological advances [10].

In light of Easterbrook's perspective, Lessig [34] offered a different approach to understanding cyberspace's unique characteristics and the challenges of integrating it into traditional regulatory frameworks. Lessig proposed four regulators of cyberspace: market, law, architecture, and social norms. Architecture refers to the regulation of cyberspace through code, which dictates its operations. Whilst this intrigues the new discussion on the potential of code as law (see [9, 37, 61], this is not within the scope of this paper. However, it is crucial to recognise the significance of technology itself in the regulatory framework. The market aspect considers how businesses respond and adapt to the internet, as its uptake depends on their actions. Social norms, meanwhile, shape user behaviour and influence the success of the Internet. Finally, the law encompasses the set of rules that regulate activities in cyberspace, determining what is permissible, establishing liability, and assigning responsibility.

Building on Lessig's work on establishing methods and norms of cyberlaw, Calo [12] posits that the law will face challenges in regulating transformative technologies such as robots due to the 3 distinct characteristics that make an artefact a robot: embodiment, emergence, and social valence. Embodiment allows robots to sense, navigate, and act in the real world. Emergence signifies a robot's autonomous behaviours lending to their ability to 'learn.' Social valence is how a robot feels different from other technology, where it is more similar to a living agent than a mere tool. Due to these characteristics, Calo [12, p. 552] concluded that robots would likely influence systematic changes to the law.

Cobots are transformative technology, a type of robot that performs as a robot co-worker rather than performing tasks independently and only co-existing in the same space as humans. Calo's statement has highlighted the need to reevaluate the current legal doctrine, but we have been warned that this may require the formulation of a new legal doctrine. Will *Cobot Law* be necessary?

The lessons learnt from cyber law and robot law provide valuable insight into Cobot regulation. We find that the regulation of emerging technologies requires a greater understanding of both the technology itself and its consequential impact. To this end, it has become increasingly evident that interdisciplinary research is necessary in order to examine the role of law in this field. By examining technology from different perspectives, a more comprehensive understanding can be gained. In addition, the ubiquitous presence of the Internet instils a sense of optimism that the legal system is adaptable and constantly evolving to accommodate advances in technology. Given this historical precedent, it is reasonable to anticipate a promising future for Cobots. However, stepping from cyber law to robot law, regulating Cobots will require an integration of the need to situate technology in the wider legal doctrines and explore the potential in creating new rules to govern the emerging technology. So, before hastily establishing a new regulatory framework for Cobots, we must first assess the existing legal doctrines in light of heightened knowledge and comprehension of the technology. We will focus on addressing the liability and safety concerns associated with the adoption of Cobots.

4.3 Redress res ipsa loquitur: Let the robot speak for itself

This section examines the applicability of the current legal system in responding to the novel challenges posed by embodied autonomous systems and the proposed liability approaches discussed in the literature for addressing the complexities of dealing with robots.

Accidents can arise regardless of the actors involved, be it interactions between humans or humans and machines. However, the existing legal system has primarily been designed to address human-only scenarios, leaving those involving machines subject to more nuanced considerations. Notably, when a machine functions as a mere tool with fixed programmed functions, identifying liability for accidents is more transparent, where robot providers and/or manufacturers are held accountable for any defects or malfunctions in their products. However, if a machine possesses a certain level of autonomy with the ability to learn and adapt in a manner resembling human behaviour, determining liability becomes more complex. Traditionally, tort law relies on identifying negligence or fault attributable to legal persons [40]. However, the advent of autonomous machines that mimic human behaviours raises questions about how damages caused by such machines should be treated within the legal system.

4.3.1 What the "Law" Says. In the EU, efforts to establish regulations for robots and artificial intelligence (AI) are underway. However, as of time of writing, there are no definitive guidelines to rely on, apart from the new Machinery Regulations (EU) 2023/1230, which do not fully accommodate the concept of HRC. Nevertheless, ongoing legislative developments hold significant implications for the potential regulations concerning Cobots in determining responsibility in cases where incidents occur, leading to damages or harm caused by robots and/or AI systems.

Starting with Civil Law Rules on Robotics [14], the adoption of mandatory insurance emerges as a prudent regulatory approach. In accordance Section 57,

> *"a possible solution to the complexity of allocating responsibility for damage caused by increasingly autonomous robots could be an obligatory insurance scheme, as is already the case, for instance, with cars; notes, nevertheless, that unlike the insurance system for road traffic, where the insurance covers human acts and failures, an insurance system for robotics should take into account all potential responsibilities in the chain."*[14, Section 57]

It is recognised that robot is a complex non-human agent, comprising of component from different providers from hardware to software. In the event of an accident, insurance coverage must encompass all parties responsible in consideration to the maker and user of the robot, including robot providers/manufacturers, software provider, maintenance personnel, and even the operator. Hence, all parties involved in the entire Cobot lifecycle, from its design and development to its deployment, must collectively share the responsibilities to ensure comprehensive coverage and accountability.

The distribution of responsibilities among all relevant stakeholders may prove to be a prudent way to address damage caused by autonomous robots. By doing so, we can avert the complexities of determining fault between "unknown" causes, e.g. software failure, hardware issues, or human actions. Through shared responsibilities, we can effectively address these concerns and foster a more cooperative and accountable environment, ensuring that each party plays a proactive role in mitigating potential risks and liabilities associated with autonomous robots. This also reflects Section 59 which outlines the requirements for the mandate insurance in relation to the damage potentially caused by the robots. It also suggests possible legal solutions such as,

> *"the manufacturer, the programmer, the owner or the user to benefit from limited liability if they contribute to a compensation fund, as well as if they jointly take out insurance to guarantee compensation where damage is caused by a robot; d) deciding whether to create a general fund for all smart autonomous robots or to create an individual fund for each and every robot category, and whether a contribution should be paid as a one-off fee when placing the robot on the market or whether periodic contributions should be paid during the lifetime of the robot"*[14, Section 59].

Notably, the regulations and liability rules must take into account the distinctions among different types of robots and their respective levels of autonomy as addressed under Section 56. This provision proves particularly advantageous for Cobots, considering the varying levels of engagement and interactions they can have. For Cobot adopters, this provision serves as a valuable tool in preparing for risk assessments and ensures that they do not bear undue responsibility in respective to the type of Cobot. By aiding in the determination of risk and potential liability, this provision provides pivotal support for cobot adoption.

Moreover, when taking into account the various levels of robots, the EU Artificial Intelligence Act (EU AI Act) proposal introduces different tiers of responsibilities for AI systems. However, contrary to what was stated above in Section 56 of the Civil Law Rules on Robotics, where the operator's liability and responsibility are determined by the actual level of instructions given to the robot by the operator and of a robot's degree of autonomy, this proposal centres around AI's potential to cause harm. It is acknowledged that under Recital 63, *While safety risks of AI systems ensuring safety functions in machinery are addressed by the requirements of this Regulation, certain specific requirements in the [Machinery Regulation] will ensure the safe integration of the AI system into the overall machinery, so as not to compromise the safety of the machinery as a whole.*" As AI serves as the cognitive foundation of Cobots, software plays a pivotal role in ensuring their efficient and safe collaboration with humans. Therefore, this Regulation is applicable to Cobot.

Furthermore, in accordance with the EU Legislation in Progress Briefing, a common strict liability regime for high-risk autonomous AI systems is favourable where "operators of a high-risk AI system would be held liable when such systems cause harm or damage to the life, health, or physical integrity of a natural person, to the property of a natural or legal person, or cause significant immaterial harm resulting in a verifiable economic loss" [39]. As AI would likely to play a critical role in safety aspect of HRC, in light of Article 6, Cobots will likely to fall under the classification rules for high-risk AI systems. Moreover, Article 3(8) defines that term 'operator' as "the provider, the user, the authorised representative, the importer, and the distributor." As it refers to all stakeholders, there is still the absence of a clear direction in determining liability, which may bring us back to a debate concerning who should be held responsible for damages caused by autonomous robots. Therefore, the proposed shared insurance responsibility, as suggested in the resolution on Civil Law Rules on Robotics, could be a viable solution to support Cobot adoption. With this approach, all relevant stakeholders can collectively share the responsibilities, resulting in a more equitable and efficient resolution of liability concerns. Nonetheless, scholars appear to be reluctant to endorse a blanket policy for AI technology. Bertolini and Episcopo [6, p. 658] highlighted that "the EU should pursue continuity in its sectorial approach to regulation. AI will be used in diverse fields – from capital markets to medicine – where liability is currently regulated separately, and so they should continue to be so even when AI-based solutions are implemented."

4.3.2 Proposed Liability Approaches. In the effort to regulate autonomous machines, numerous liability approaches have been proposed, ranging from treating robots as animals to assigning "electronic personhood." Additionally, the imposition of a strict liability approach and the redressing of the legal doctrine of res ipsa loquitur in light of robots have also been put forward.

In the work by Kelley et al. [29], it may be feasible to consider robots in the legal sense as to domesticated animals, in particular the regulation for "dangerous dogs," in grappling with the complexities of autonomous robots that have a degree of independent decision-making and control over their actions, distinct from remotely controlled or pre-programmed robot. From a perspective of a robot involving in an accident and found to be free from defects, the courts should assign liability to both the victim and the robot's owner based on the same principles, which are domesticated animals. The authors also proposed strict liability for robot providers/manufacturer in instances of robot defects while holding owners accountable for negligence, such as damages caused by the robot's unpredictable behaviours resulting from inadequate maintenance and wear and tear. The authors recognised that in Europe harms caused by domestic animals can result in criminal and civil penalties, categorising them into "dangerous dogs" and "all other dogs." The idea of classifying robots based on their potential to cause harm is also shared by the EU approach to the AI Act.

Therefore, in the same ways as domesticated animals, robots cannot compensate for potential damages they may cause, this perspective allows for a more coherent and practical approach in addressing the liability challenges associated with these advanced technologies. This proposal may be more applicable in the context of domestic robots but the underlying principles can be applied in the context of industrial workplace. As Cobot's adopter, the manufacturers will still need to ensure safety and routine maintenance of Cobots in order to ensure safety because they can still be held liable for harms caused to the employees.

On a different discussion, could a Cobot ever be considered as a legal person (i.e., "ePerson") where it can be considered as a wrongdoer and qualified as liability subjects based on tort law? Granting a robot legal personhood is certainly a highly contentious debate (see [43]). In fact, machines should not be regulated in a similar manner to people as Eidenmuller [17, p. 133] argued *"our laws are an expression of the human condition. They reflect what we believe lies at the heart of humanity, at the heart of what it means to be human. It simply and literally would be the dehumanising of the world if we were to treat machines like humans, even though machines may be smart—possibly even much smarter than humans."* Though it was viewed that a concept of an ePerson could help simulate innovation given that it provides *"protection of manufacturers and users from excessive liability"* [56, p. 612].

Wagner [56] argued that the reach the same outcome on determining liability of robot providers and/or manufacturersand users, it is simply unnecessary to create a new legal entity as ePersons - bearers of rights and duties and holders of assets in a similar way to a corporation. To hold a robot as an ePerson liability for damages will require a robot having minimum asset requirements which robot providers and/or manufacturers and users would have to contribute to this asset pool. However, this can still occur if these parties were obligated to obtain mandate insurance for the robots, as also proposed in Civil Law Rules. This indicates that the necessity of creating a new legal entity such as an "ePerson" to address liability issue in the context of insurance may not be required.

Although it has been concluded that robots should not be granted legal status, the question of how to address the accidents caused by Cobots, as a new cause of harm, still remains. Guerra et al. [23, p. 332] raised a concern that "as the level of robot autonomy grows, under conventional torts or products liability law it will become increasingly difficult to attribute responsibility for robot accidents to a specific party." The scholars proposed a liability model addressing that "a fault-based liability regime where operators and victims bear accident losses attributable to their negligent behaviour, and manufacturers are held liable for non-negligent robot accidents called 'manufacturer residual liability'" [24, p. 340].

With a fault-based liability regime, the process of determining the extent to which each party should contribute to compensate for their negligent behaviour may be challenging. This complexity arises from the possibility of attributing blame solely to the autonomy of the robot and its unpredictable actions, which could lead to the argument that the incident was not a result of negligence Casey [13]presented a different approach in applying tort law in the case involving robots. The author highlighted that *"tort law doesn't require that plaintiffs pinpoint direct evidence of accident fault in a faulty line of software. Instead, the legal rule of res ipsa loquitur allows plaintiffs to show fault through inference even in accidents involving confoundingly complex machines"* [13, p. 252]. Casey [13] suggested that in investigating accidents, accessing to the data recording technologies embedded in robots is highly crucial. From the recording, authorities should be able to draw the inference of negligence, thus, "the robot, in other words, speaks for itself" [13, p. 233].

This is also supported by Wagner [56] where the data stored in the "black boxes" installed in autonomous systems will enable victims to readily and precisely identify the party responsible for any incidents. Therefore, in tort problems involving the determination of liability for damages due to negligence, data can often infer negligence. In the context of robots, the doctrine of res ipsa loquitur, which means "the thing speaks for itself," may be complicated. When an accident occurs involving a robot, access to relevant data can allow for drawing inference of the cause. This facilitates the process of attributing responsibility and liability for the damages caused.

In the future, it is plausible that Cobots may require a distinct set of regulations when the existing legislation can no longer cope with the challenges arising due to the nature of highly advanced autonomous systems. Alternatively, it might be necessary to amend the current regulations to address the data that should be retained by Cobots. However, until an intervention takes place, the adoption of data logs as evidence in handling liability cases related to data seems to be the most plausible and feasible approach. Therefore, this puts data as a pivotal and central point in Cobot regulation. In the next section, we will discuss the implications of data from the context of health and safety and the need for inclusion in data training requirement for Cobot safety.

4.4 Data Meets Health and Safety Regulations

We posed the question of whether Cobots should be subject to a separate, more stringent regulation in addressing safety and liability challenges. We proposed that given how data plays a crucial role in determining negligence, it should also be regulated in the context of safety regulations, wherein the responsibility rests with the robot adopter. As Cobots are integrated into work environments, manufacturers are obliged to ensure the adoption is aligned with health and safety regulations. It is important to the data utilization in training robots to ensure their safe interactions with diverse users to minimise algorithmic bias. For example, designing robots that are trained with data from a specific demographic, such as 6'1" Caucasian men, could be considered a breach of the Health and Safety at Work Act if it leads to a situation where the robots are deemed "not reasonably safe" for interactions with individuals from diverse backgrounds.

Cobots interact with humans and making 'judgements' about the humans through the collection and processing of personal data, such as data derived from user behaviors, facial expressions, voice, and biometric data (e.g., heart rate sensoring) to adapt to their performance, as observed in the mentioned article [3]. If the robots are training on poor data sets, this could have implications on how the robots will behave in the real environments with different users. For instance, if a robot recognizes and responds to a male voice better than a female voice during the operation, this form of discrimination raises safety concerns. Therefore, failure to address such bias can result in hazardous workplace scenarios. In tackling this challenge, it should be highlighted that the responsibility for Cobot safety lies with both the manufacturer adopting Cobots (acting as the employer) and the Cobot provider/designer.

In the UK, Health and Safety at Work etc. Act 1974 the employer has the duty to "ensure, so far as is *reasonably practicable*, the health, safety and welfare at work of all his employees," where the duty includes:

> *in particular(a) the provision and maintenance of plant and systems of work that are, so far as is reasonably practicable, safe and without risks to health; (b) arrangements for ensuring, so far as is reasonably practicable, safety and absence of risks to health in connection with the use, handling, storage and transport of articles and substances [...]* [25, Section 2]

In light of Section 40, reasonably practicable actions should be interpreted as taking all possible actions until it is *"not reasonably practicable to do more than was in fact done to satisfy the duty or requirement, or that there was no better practicable means than was in fact used to satisfy the duty or requirement."* This places the employer in a position of responsibility to prioritise the protection of employees at all costs, thus playing a crucial role in safety of Cobot adoption since they are in the position in determining how and which Cobots are adopted in the workplace. Therefore, companies will be held accountable if any accidents occur due to inadequate assessment in Cobot design or failure to ensure that they procure, to the best of their knowledge, suitably designed Cobots.

Furthermore, Health and Safety at Work etc. Act [25] Section 6 requires that,

> *"it shall be the duty of any person who designs, manufactures, imports or supplies any article for use at work or any article of fairground equipment(a) to ensure, so far as is reasonably practicable, that the article is so designed and constructed that it will be safe and without risks to health at all times when it is being set, used, cleaned or maintained by a person at work; (b) to carry out or arrange for the carrying out of such testing and examination as may be necessary for the performance of the duty imposed on him by the preceding paragraph."*[25, Section 6]

Under Section 53 'article for use at work' means *"(a) any plant designed for use or operation (whether exclusively or not) by persons at work, and (b) any article designed for use as a component in any such plant"* whereas "plant" includes any machinery, equipment, or appliance.

As part of Cobot safety assessment, it is the robot provider and/or manufacturer's responsibility to address all aspects contributing to the technology's safety, including the incorporation of appropriate training data for Cobots. Biased and discriminatory algorithmic decision-making can lead to unsafe interactions, making it a case of health and safety regulations. In such instances, it becomes the designer and/or manufacturer's responsibility to ensure workplace safety, and data used in Cobot design and training should have been addressed within the health and safety risk assessment.

In addition to training data, the technology requires data to be collected to perform its tasks and interact safely with its environment [4, 5, 21, 55]. Even though the constant data processing can be argued from the perspective of safety monitoring or even considered as evidence in the event of accidents, this could raise concerns about over-monitoring or surveillance practices. This can lead to increasingly problematic privacy issues given the constant interaction of robots with humans [22, 33]. Hence, given the pivotal role of data in Cobots, the adoption of Cobots in the UK and the EU will necessitate a data protection impact assessment in accordance with the General Data Protection Regulation (GDPR). [1]

5 DISCUSSION AND CONCLUSION

Cobots introduce new risks and challenges to manufacturing sectors where machines and humans are traditionally kept separated. Emerging technology might have been expected to challenge or even break the legal system, pushing and blurring the boundaries of legal doctrines. However, this is not the first time that the law has encountered this problem, as seen with prior innovations such as the Internet. Furthermore, the introduction of Cobots may not inherently threaten the existing rules of law; rather, it is the uncertainties surrounding this technology and the associated risks that have presented challenges in reviewing its adoption within the legal context. Notably, Cobots still have technological limitations in reaching a truly collaborative nature. Therefore, the law is adequate in governing current Cobot forms.

Nevertheless, we recognise that there is not a well-defined legal framework specifically tailored to Cobots. We posit that, rather than developing novel legislation, it is more prudent to apply existing legal frameworks to Cobot adoption. Although current machinery regulations recognised the machine design for a form of human-machine interaction, the safety requirements did not seem to fully support direct collaboration between human and robot. However, that does not mean the law is not applicable to Cobots in particular

[1]We acknowledge the ongoing development in amending the UK GDPR; however, as of the time of writing, the UK GDPR remains in effect. Since the subsequent sections address data protection principles that remain unaffected by the amendment from the EU GDPR to the UK GDPR, we will refrain from delving into the distinctions between the two regulations and continue with the original GDPR as of REGULATION (EU) 2016/679.

given that the current stage of Cobots still does not allow for proper collaboration.

Furthermore, from liability perspectives, many approaches can be taken to address damages caused by Cobots and the case of negligence. In particular, we found the proposal on insurance and data retention to be the most suitable for Cobot adoption. Data also plays a crucial role in ensuring safety for HRC which should be addressed under health and safety regulations. Although the retention of data collected by Cobots containing personal data may conflict with data protection principles, the analysis shows that adequate safeguards and measures can be put in place to address the challenges.

In addition, the notion that law is an adoption barrier or innovation killer needs to be revisited. In reality, the law makes technology safer by holding technology designers and/or manufacturers accountable, resulting in a longer research and development stage to ensure safety and functionality. This point is demonstrated from the perspective of HRC with training data and data processing to addressing surveillance to addressing rights of employees in association with working with robots. Contrary to expectations, the regulatory gap is not significant, as the law can effectively influence robot safety and clarify liability concerns.

From a policy perspective, law and regulation have shown significant progress when recognised as needed. Since 2018, we have witnessed considerable development in policies and regulations for advanced industrial robotics, such as Industry 4.0 support regulations (UK), proposed AI Act (EU), and the replacement of the 2006 Machinery Directive with the Machinery Regulation 2023 [19]. However, we have not seen much progress for Cobots in manufacturing. Initially, regulations may have been paused to encourage innovation, but as the sector matures, countries prioritise the safety of autonomous systems. From our observation, we find that the development rate between law and Cobots is not as far apart as previously claimed. The development of Cobots is not yet ready or suitable for true human-robot collaboration. Therefore, regulations can move fast, and it seems that with emerging technologies coming through, a more proactive approach is being considered. The key lies in fostering interest in understanding the impact of technology adoption in order to drive more innovation towards regulating technology.

We conclude that the existing legal frameworks are adequate in addressing the potential safety, liability, and data privacy challenges and implications arising from Cobot adoption. The ubiquity of the Internet is an example of how the law can adapt and evolve with technology. However, as we learn from cyber law, achieving responsible Cobot adoption requires more than just legal requirements; consideration of market dynamics, architectural factors, and social elements also plays a role, as Lessig emphasised [35]. A holistic approach that addresses these aspects will be instrumental in ensuring the successful integration and adoption of trustworthy Cobots. Nonetheless, for future work, as Cobots are advancing and when technology finally gets to that point of full human-robot collaboration, a new way of regulating Cobots and emerging autonomous systems may be explored.

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