International Journal of Social Robotics
https://doi.org/10.1007/s12369-019-00553-8

Religion and Robots: Towards the Synthesis of Two Extremes

Gabriele Trovato[1] · Loys De Saint Chamas[2] · Masao Nishimura[3] · Renato Paredes[4] · Cesar Lucho[5] · Alexander Huerta-Mercado[6] · Francisco Cuellar[7]

Accepted: 25 April 2019

Abstract
Humanity has been dreaming of robots since the ancient times. Historically, robots — originally called automata — have been the products of technology and faith. The relationship between robots and religion has disappeared in the last two centuries, as science and religion parted ways, and have typically been seen in opposition. Nowadays, as robots and AI are going to spread in human society, new possibilities and new ethical challenges are on the horizon. In this paper, we summarise the state of the art in robotics and religion, and propose a taxonomy for robot morphology that takes into account the factor of religion. The taxonomy encompasses the novel concept of 'theomorphic robots', referred to robots that carry the shape of something divine.

Keywords Religion · History · Design · Social robots

1 Introduction

Through history, religion has moved between different steps of technology. The oral tradition of the beginnings turned into writing; from handwriting to printing books. The invention of printing press had an important impact, for instance, on the diffusion of the Bible and at the same time on the strict control of the content by the Catholic Church. Even icons followed the same evolution—from painted to printed: the industrialised iconography may lower the spiritual level of the art, because of the lack of human dedication, although it facilitates diffusion. A controversy of this kind arose about the Saint-Sulpice style [1] stained glasses. The advent of mass communication brought the questioning whether a ritual has the validity if attended by phone or by television. The common thought that at each technological leap, religious authorities are typically cautious, being servant of the tradition and of the status quo, is not always true [2]. The Catholic Church also historically revised its own model in order to face different contexts [3].

✉ Gabriele Trovato
gabriele@takanishi.mech.waseda.ac.jp

Loys De Saint Chamas
p.loys@free.fr

Masao Nishimura
masao@waseda.jp

Renato Paredes
renato.paredes@pucp.edu.pe

Cesar Lucho
di.ce.lucho@gmail.com

Alexander Huerta-Mercado
ahuerta@pucp.pe

Francisco Cuellar
cuellar.ff@pucp.pe

1 School of International Liberal Studies, Waseda University, 11-1430, 1-6-1 Nishi-Waseda, Shinjuku-ku, Tokyo-to 169-8050, Japan

2 Notre Dame de Vie Institute, 205 Chemin de Sainte-Garde, 84210 Saint-Didier, France

3 Graduate School of Letters, Arts and Sciences, Waseda University, 1-24-1 Toyama, Shinjuku-ku, Tokyo 162-8644, Japan

4 Department of Psychology, Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel, Lima, Peru

5 Department of Industrial Design, Delft University of Technology, Delft, Netherlands

6 Anthropological Section, Department of Social Sciences, Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel, Lima, Peru

7 Mechatronic Specialty, Engineering Department, Pontificia Universidad Católica del Perú, Av. Universitaria 1801, San Miguel, Lima, Peru

Published online: 07 May 2019

Robotics in religion may be intended as a novel step in these regards, whose consequences have still to be clarified. Despite the strict separation between religion and science, the rise of robotics and AI is raising new questions that also involve religion. With the advent of various kinds of new technologies, human societies will be increasingly designed and constructed with their dependence upon what these technologies can achieve. While technology changes the way people practice religion [4], and possibly enhance spirituality [5] it could also be argued that technology may transform concepts of religion, myth and spirituality [6]. In this paper we begin to shed light on this matter.

1.1 Robotics and Social Relevance

As robots are expected to fulfil a role of support in human life, appearance of robots is a matter of critical importance to facilitate interaction with people [7]. Task role of robots in human society is also related to anthropomorphism regarding acceptance from the users [8].

Moreover, several studies have shown that the cultural background affects the attribution of some form of personality to robots [9], as well as the degree of anthropomorphism and expectations and preferences about their role in the society [10]. Numerous previous studies, such as [11–14] in robotics focused on the acceptance of robots depending on background culture of the users, however bypassing the religious factor.

Conversely, the root of the different attitude across different countries and cultures towards robots comes also from the religious background [15]. With the due differences and traits in common among religions, robots have historically been cultured objects, the products of technology together with faith [16].

Religion is a topic that should not be overlooked in robotics. In the past, a complex array of deities and divine creatures served as models of human behaviour for commoners and elite [17], and even nowadays religions shape the societies our our world. Christianity and Islam are the two most widespread religions (respectively, 31.5% and 23.2%) [18].

At the same, religion is socially important as numerous studies reported the evidence of an association between religion and physical [19] and mental [20] health and well-being. Elderly people could benefit from daily conversation with an artificial personality rather than being alone and lonely [6]; however, their interaction with robots is a very sensitive matter regarding their acceptance, as they often experience difficulty in the use of technological devices [21] such as mobile phones. Even recent surveys [22] highlighted that the positive view of robots decreases with age, with the due culture-wise differences. Therefore, the process of design of social robots is a factor of critical importance to ensure acceptance in particular with certain types of users, and the use of religion may be a key to achieve acceptance. In fact, since religious objects are commonly familiar to elderly people, they may not feel distress in the interaction with a robot that is related to his/her own religious background.

1.2 Antropology

In anthropology, robots and religion have been discussed. McIntyre [23] discussed about the relationship between the concept of robot and 'Romantic Transcendence'. Foerst [24] discussed two distinct anthropologies—Christian and scientific—and how building humanoid robots can stimulate to think about the concept of personhood. Higgins [25] associated gods and monsters as both within the Uncanny Valley. Vidal [26] made a comparison between human–robot interaction (HRI) and human–god interaction (HGI), given empirical studies on rituals in Hinduism. Durkheim [27] stated that gods are also a projection of humans, made to mirror our social values and keep them in order to survive as a society.

A final glance to the present and future: as evident in many science fiction stories [28] and interaction with current humanoid robots [29], humans' relations with the artificial intelligence and robotic technology manifest a certain kind of holiness. Similar to the divine power, which awes, shocks and frightens and at the same fascinates with the promise of salvation, robot technology in people's minds threatens through dehumanisation, transhumanism and even extinction of human race, while at the same time fascinates through the promise of a longer or eternal life [28]. This relationship may even reach the point in which a superhuman intelligence is worshipped by humans, in a similar way to the so called "Cargo Cults" happened after World War II, when indigenous peoples from isolated Pacific islands came into touch with US army and later developed a cult for their inexplicable technology [30]. Asimov instead imagined a scenario in which robots perform their job just in the name of a deity and of its (robotic) prophet rather than by obeying the three laws for the benefit of the humans [31].

In conclusion, throughout the ages and the cultures, robots always raised questions on divine creation and whether it can be replicated by humans, and we can take inspiration from the past to face today's world challenges [16].

1.3 Angelology and Embodiment

Robots and religion as synthesis of the two extremes can be better understood by looking at the field of Angelology. For centuries, theologists and philosophers, across various religions, spent effort in the study of angels. Angelology enquires about the existence and the nature of angels, considered as

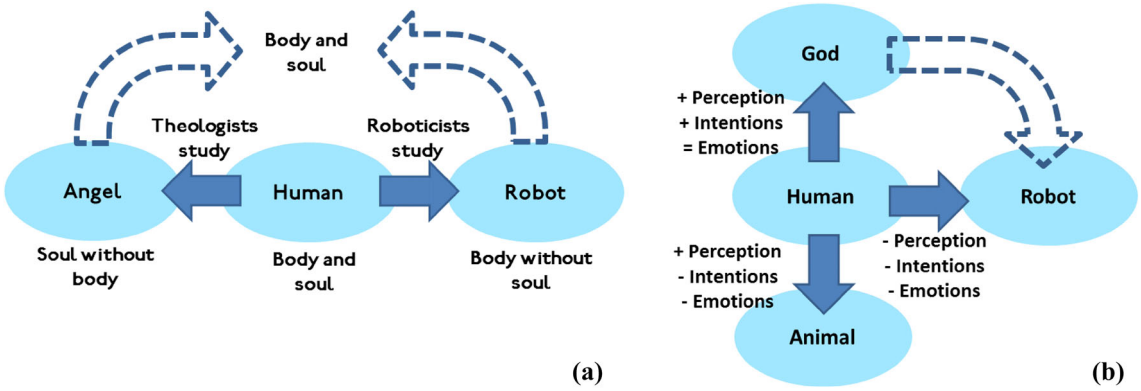

Fig. 1 Concept of robot as opposed to angel (**a**) and within dehumanisation (**b**). Based on Haslam's work, we marked with "+" and "−" the capacities that a God, an animal and a robot respectively feature or miss, compared to a human, and with "=" in case of capacities in common

"soul without body" [32]. This study has the further effect of shedding light on human nature.

Humanoid robotics then could be considered specular, as it is the study of "body without soul" and it leads to a deeper understanding of the human nature, especially thanks to the realisation of androids and the Uncanny Valley hypothesis questioning on human specificity.

At the same time, building robots and developing AI make us understand the complexity of the creation and the implications of embodiment. We can make a step further: connect the two extremes (Fig. 1a), by embodying the divine by using robots, or projecting divine essence into a machine. The result can lead to an even deeper understanding of humans and their soul/body duality.

An important contribution to the concept of human nature and humanoids has been given by Haslam [33]. He proposed an integrated theory on dehumanisation, involving the denial of two different types of humanness: characteristics than are uniquely human (UH) and those that constitute human nature (HN). This results in two corresponding forms of dehumanisation: "animalistic" and "mechanistic".

A human deprived of his UH would be perceived as irrational, driven by instincts, as an animal, and considered as "subhuman"; while a human without HN would be rather a cold, rigid "nonhuman": an automata driven by causes rather than real intentions. This latter is a common depiction of robots. This depiction can intended also in positive sense, as by the XIX Century German poet Von Kleist, who identified the human deprived of intentions and self-consciousness, and God, as of the same essence of perfection [23]. However, the nonhuman generally does not have positive connotations.

In Haslam's subsequent work [34], his theory was confirmed by data collected from people from three different cultures (Australia, China and Italy). The concept of superhuman was also introduced for comparison. Results showed that supernatural beings were seen as having superior cognitive and perceptual capacities compared to humans, while robots are seen as lacking emotions and desires. Results regarding perception and intentions are summarised in the trichotomy in Fig. 1b. In that experiment, robots were evaluated considerably worse than animals.

Similarly to what we suggested for Angelology, we pose a new question: what happens if we project some divine essence from the superhuman to the robot (dashed arrow in the figure). We hypothesise that it might be possible to improve robots impression and their interaction by projecting some qualities attributed to a deity, hence realising a "super-nonhuman".

1.4 About This Paper

The material realisation of the dashed arrows in Fig. 1 is what we will call "theomorphic robots". Theomorphic is a word that derives from Greek: god (*theo*) + shape (*morphé*). The word implies that the robot is shaped in a way to resemble something divine, as opposed, for instance, to anthropomorphic (shape of human) or zoomorphic (shape of animal). Arguing about the shape of a god in a robot may seem ambiguous; however we intend the meaning of theomorphic as a robot which is designed with a shape, and carries the identity, of something supernatural. Any representation of a deity, a mythical creature or a sacred object belongs to this category. We will go deep into the discussion of what this category of robots implies.

This manuscript aims to be the reference review paper for the topic of religion and robotics, and adds the theoretical contributions of a taxonomy for robot design and the novel concept of theomorphic robots. The theories we discuss are a further development of the contents introduced in our previous works [35, 36].

In the introduction, we presented different point of views regarding this topic. The rest of the paper is organized as follows: in Sect. 2 we make an overview, religion by religion, of the history of the involvement of technology and robotics;

in Sect. 3 we categorise the state of the art of automation in religion; in Sect. 4 we illustrate the taxonomies; in Sect. 5 we offer concrete design guidelines for theomorphic robots; in Sect. 6 we present two prototypes and the following ethical discussion. Section 7 is the conclusion.

2 Religion-Wise Historical Relations With Robotics

In this section, we will see a survey of the different views of robots and more generically technology among world religions.

2.1 Ancient Greece

Humanity has always been dreaming of robots, since the time of Ancient Greece and its mythology. In the Iliad for example, Hephaestus, the god of metalworking, created artificial servants. These kind of objects were made by the gods to serve the gods. Their divine essence is however combined to a degree of human-likeness, as the humankind is also made in a divine image [16]. In the myth of Pygmalion instead, the protagonist made a statue of a woman and fell in love with it, then Aphrodite gave life to it, naming it Galatea [37]. In each of these cases, robots played the role of mirror of humans. Another myth is the one of Talos, a legendary bronze giant. It was commissioned by Zeus and built by Daidalos and Hephaestus to protect Crete.

Some of these ideas could be concretely realised in the form of automata. An automaton is defined as a "mechanical model of a living being". The purpose of automata consisted in their ability to surprise and amuse [38]. The book *Automatopoeica* by Philo of Byzantium which described the construction of automata, has unfortunately been lost. However, we still have some remaining knowledge. Remarkable examples of automata of the past were statues that spoke and made gestures, actuated by priests [39]; the 4.5 metres mechanical tall statue in Alexandria resembling the goddess Isis; and the works made by Hero of Alexandria. Hero used the concept of wonder to add an intellectual component to the utility of mechanics, to relate such mechanical expertise to divine intelligence [40]. Hero's concept of "useful wonder" is applicable to modern robots too, and he was the first to even deal with the concept of suspension of disbelief and Wizard-of-Oz, defining in his work *Automaton-construction* a maximum size for the automatic theatres and suggesting how to hide the mechanics, in order that the audience does not suspect that there is a person inside pulling the strings [40]. Among his works, it is worth remembering the fire-blazing altar to Dionysus, and the sitting and standing statue of the goddess Nysa, as examples of automaton applied to religion, or more correctly, to mythology. Hero goes even deeper in these applications, describing devices which are explicitly stated to be for use in religious practices in temples [40].

Although not classifiable as automata, from the writings of Herodotus [41] we also know about puppets moved by strings being used in religious festivals [42]. The tradition of using puppets was probably imported from Egypt, where for instance, the dog-headed god Anubis was represented by using moving jaws, and later was exported to Rome [43].

2.2 Christianity

Christianity is typically seen as keeping an opposing stance towards technology. However, this has not been always the case. Among automata made in the Middle Ages, besides wealthy people, the main patron of automata was the Catholic Church [44]. The goal was to amaze and delight, by using movements that appeared impossible could only be explained by magic. By the line between religion and magic, the Church kept spreading faith through the power to astonish, making use of an "enchantment of technology" [45] that was effective for that time. From a design point of view, this was achieved by having the robotic element hidden: showing lifelikeness of automata and the impossibility of distinguishing them from the object of inspiration. Though the Middle Ages and later, mechanical angels and fire-breathing devils were designed. Automata brought to life biblical passages, such as in the automaton crucifixion scene, from ca. 1700, made of wood and in which the figures move [16].

One of the early modern examples of mechanisation of faith is the clockwork monk, built for Philip II of Spain in the XVI Century [46]. Iconographic indications of the monk's appearance suggested that the identity is of San Diego. Its mechanism concealed underneath the wooden body enabled the monk to pray and kiss a rosary among other simple movements. It is speculated that the monk was a votive offering, in the sense that God himself was the intended audience, because no one else could see the concealed mechanism [47]. A similar figure, believed to also represent a saint, featured comparable head, mouth and eye movement, and was 41 cm tall [48].

Since the 18th Century, robots have associated less with faith and magical symbolism, and more with efficiency, as the power of creation has shifted from gods to humans. Furthermore, different perception of robots, due to a change of the definition of aliveness between the 16th century, the time of the mechanical monk, with nowadays, make the enchantment of technology less effective, and mark a difference in the suspension of disbelief [47].

2.3 Islam

The most important issue in Islam with robotics is about iconoclasm: the anti-iconic doctrine of prohibition of depic-

tion of symbols and religion icons. According to it, depiction of living beings, either animal or human, has been avoided, especially in sacred spaces, as depicting an image of a living being would be considered same as adopting the role of creator, which is reserved for only God [49].

From Sahih al-Bukhari 7557: Allah's Messenger said, "*The painter of these pictures will be punished on the Day of Resurrection, and it will be said to them, 'Make alive what you have created.*'".

From Sahih al-Bukhari 3225: I heard Allah's Messenger saying; "*Angels (of Mercy) do not enter a house wherein there is a dog or a picture of a living creature (a human being or an animal)*".

Therefore, iconoclasm should be considered as a potential problem and definitely as an influencing factor on the attitude of people of Islamic countries towards especially humanoid robots. In the Middle East, where society rules and state laws are often blended with religious beliefs, the understanding of cultural norms of the country is particularly necessary for ensuring technology acceptance [50, 51].

Iconoclasm, however, is not necessarily a common issue to all the Islamic world. For instance in India, one the largest Islamic countries by population, where the Sufi orders were strong and presence of magic/superstition is documented [52], the way to intend Islam has been different from the Middle East. This can be seen in the Indian subcontinent regarding theology (see the mystical symbolism of the traits of the human face [53]) and the construction of automata, of which one famous example is the tiger of Tipu Sultan [54].

Recently, a debate has been raised as in Saudi Arabia, the android Sophia has been granted citizenship, questioning about the comparison with human females in their obligations in Islam. The nature of Islamic faith, which requires rituals to be performed on daily basis (prayers), on yearly basis (Ramadan) and once in a lifetime (pilgrimage to Mecca), also raises questions about the physical presence in a ritual. For those who are physically impaired and cannot perform such rituals, a robot could definitely be of help. The degree how of how much delegation to a robot will be allowed remains an open question.

Nevertheless, the recently developed android IbnSina [55] received a relevant share of media attention, and interacted with thousands of visitors in fairs around the Middle East.

2.4 Hinduism

Even before the aforementioned cultures, in the Vedic civilization (ancient India) there are references of advanced technology in ancient texts such as Bhagavata Purana and Ramayana. In fact, the Sanskrit term *Yantra* may be translated as machine or, perhaps, robot. Particularly, in Yoga Vasishta [56] it is mentioned that an Asura named Sambarasura created three robots: Dama, Vyala and Kata, which are described as war machines without sentiments that were employed to defeat the Adityas. Similarly, in the Mahabharata [57] there is a reference of a gigantic human-like machine named Kumbhakarna who was employed by Ravana in its war against Rama.

Puppet shows were also a tool to convey stories regarding Hindu gods and Puranic legends [43] and promote Hinduism.

Nowadays, in modern India initial efforts are being carried out to include automatisation and robotics as means of Hinduism cultural diffusion, such as Ganapati Bappachi Robotic Aarti [58] developed by Robolab Technologies or the animatronics show displayed in Akshardam in honour to Swaminarayan. Grimaud [59] investigated in the processes of mechanisation used for Hindu rituals, and performed a social experiment with a robotic version of the elephant-headed god Ganesha, which was teleoperated not only by the experimenters but also by some believers, who experienced the impersonation of the god.

Hinduism conceives God as a multiplicity and accepts different ways of worship. We argue that this inclusive nature of Hinduism (also regarding other religions) may help in the acceptance of automatisation for the repetition of rituals.

2.5 Judaism

The most interesting story about Jewish folklore and robotics revolves around the golem, a man-made creature built from clay or mud. The earliest stories mention only its inability to speak. Eleazar ben Judah in the twelfth century described how to create a golem. Judah Loew ben Bezalel, in the sixteenth century, reportedly created a golem which went out of control and had to be destroyed. This story, an example of *hubris* in the arrogance of man in moulding a living creature, can possibly be the origin of the fear of man-made creatures also later known as "Frankenstein complex" or "Frankenstein syndrome" [60].

Idel [61] explored the historical and intellectual frameworks in the Jewish traditions concerning the golem. According to Foerst, the act of golem building is itself a prayer, as it desconstructs the mystery of what it means to be human. The matter of embodiment, which is common to religion as well as robotics, is discussed in [29].

In Jewish Orthodoxy, the relationship with technology is particularly interesting. Woodruff et al. [62] describe a study involving Orthodox families while using a wide range of objects that automatise the tasks.

Sabbath is the day of rest in Judaism: from the sunset of Friday to the sunset of Saturday, for Jews it is the time to rest, mirroring God's creation of the world for 6 days, leaving the last one for rest. During this time, not only working is prohibited by strict observance, but also a long list of activities, such as lighting a fire. In the modern interpretation, this corresponds to prohibiting switching an electrical device on

and off. This fact caused the flourishing of home automation systems for the Sabbath. They enable to perform activities in advance before the Sabbath begins. Some of the timers regulating forbidden activities reportedly proved to be useful for the entire week.

Overall, automation can be intended as a spiritual support. It does not only circumvent the prohibition of work: it also relieves from the burden of any activities, freeing up people's mind, enhances the Sabbath experience, and teaches to accept God's will even when the automation has some failures [62]. Automation may also be seen as a modern extension of using human slaves to perform forbidden activities [63].

2.6 Eastern Religions

East Asia has been characterised by the influence of waves of spirituality often originating from India, and by common ideals [64]. In Asian countries it is possible to encounter many different shades of people's religion, as Confucianism, Buddhism, Taoism and Shinto are not reciprocally exclusive, and influenced each other in different ways in different countries. Among them, some common lines can be found.

In particular, the dualism of mind and body compared to monotheist religions led to different conclusions and approach in the research in robotics [15]. Within Buddhism, the most important contribution is by Mori [65], according to whom, "robots have the Buddha-nature within them" and "the potential for attaining Buddhahood". Mori's words shed light on Japan's unique relationship with the inanimate: stating that robots deserve from us the same compassion we offer to all living beings, and that humanoid robots reflect the essence of Buddhahood, which is compassion.

Historically, in southern China and Sri Lanka, Buddhism was spread also through the use of shadow puppets [66] and images of gods and goddesses moving hands. China has a long tradition of shadow puppets, which have also been used to bring back alive the spirit of the dead on a shadow screen [43]. Tradition spread from China to Korea, where puppets were thought to come in god's image, and were used in Yeondung and Palkwan festivals for special occasions, such as the commemoration of Buddha's birthday, and as idols for ancestral worship [43].

In Shinto, the emphasis on nature worship leads to the belief that inanimate things are sacred objects at its core. One possible explanation [67] lies in the Confucian animistic conception of religion, that ascribes souls to all living and non-living objects.

The particular case of Japan is important because of the tradition of Karakuri puppets [68], ancestors of modern humanoids. These puppets have been introduced in temples and shrines since the Muromachi period, which starts in the 14th Century. This may have pushed Japan to a world leading position in the development of humanoids, combined to the lack of the Frankenstein complex and to the ancient roots of anthropomorphism, already present in the twelfth century in the animals depicted in the Chōjū-jinbutsu-giga scrolls [69].

Nowadays in Japan, there are a few cases of automated technology for death. The humanoid Pepper has been used by the company Nissei Eco for funerals [70], while the Automatic Conveyor-belt Columbarium [71] manages gravesite spaces combining physical and digital remains of the deceased.

3 State of the Art of Automation in Religion

Related works in this field are relatively scarce. We illustrate the state of the art, to our best knowledge, in Fig. 2, parting them following two criteria:

- Theomorphic versus non-theomorphic.
- For religious use versus for other uses.

Examples are reported group by group as follows:

(A) In the figure, in the bottom left-hand side we reported a few social robots that are not related to religion in any sense, but that will be mentioned later in the description of the taxonomy, and we keep them for comparison. Geminoid-F [72], KOBIAN-R [73], Himawari [74] and Aibo [75].

(B) In the left-hand side, across the two categories of use we place two examples of automation: the $\times 10$ timer for Jewish Sabbath [76], and the android Ibn-Sina [55]. Both of them are tools that can be used for a religious purpose as well as for non religious one. Timers are a supporting technology for Jewish Sabbath, but they can also be used in other normal days. The android IbnSina is inspired to the historical person, who has been an important scientist and philosopher during Islamic Golden Age. The robot's teaching can respectively span from scientific to theological.

(C) In this group in the top left, we placed icons the state of the art of robots recently made for religious use. BlessU-2 [77] is a humanoid made in Germany to mark 500 years since the Protestant Reformation. It delivers various blessings in eight languages. Xi'aner [78] is a "60-cm tall robot which resembles a cartoon-like novice monk in yellow robes with a shaven head, holding a touch screen on his chest. It can hold a conversation by answering about 20 simple questions about Buddhism and daily life, listed on his screen, and performs some motions on its wheels." It has been built to spread Buddhism in China. In the third picture, a robotic arm is performing a ritual for Ganesha [58]. In the second row, the Prayer Companion [79], a device developed for

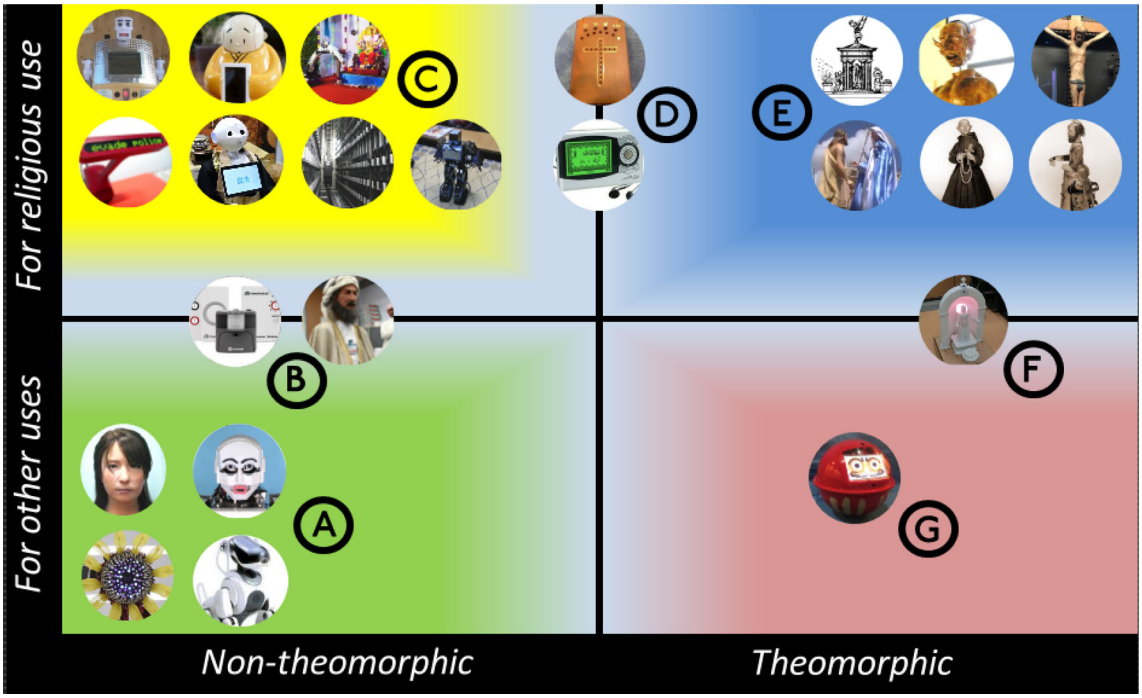

Fig. 2 State of the art of robots, automation and technological devices involved with religion

supporting the spiritual activity of a group of cloistered Christian nuns. The humanoid Pepper [70] is currently being used in funerals. The Automatic Conveyor-belt Columbarium [71] automatises gravesite spaces. Veldan [80] is a readaptation of the Robotis Bioloid robot kit to the use as an Islamic prayer instruction device. The information about it on the web is scarce.

(D) This group stands in between theomorphic and non-theomorphic categories. This is because the potential perceived sacredness is partial. This is the case of any Christian electronic rosary, and of an electronic Quran, which carry a sacred message (and in some cases symbols), while being just technological products.

(E) Automata and actuated representations of the divine through sacred art are theomorphic and made for religious use. The group includes the altar to Dionysus, the devil automaton [81] made in Italy in the fifteenth to sixteenth century, the automaton crucifixion scene made in France in the eighteenth century, and actuated statues used in Catholic processions. The mechanical monk [47] and the mechanical saint [48] are also made as a work of sacred art, although what they portrait, however, is not a deity but just a holy person. The goal of all these works was/is to amaze the believers.

(F) The theomorphic robot SanTO (Sanctified Theomorphic Operator) [82] stands in between the two categories of use because it is not only a praying tool, but also a companion that can be useful for elderly persons' well-being.

(G) DarumaTO-2 (Daruma Theomorphic Operator), while representing a talisman of Buddhism and Shinto, has only an application in healthcare and it does not serve for praying.

The top/bottom distinction about the use is pretty much self-explicatory. Certain design paradigms may have to be followed in order to develop a technological device for religious use, as suggested in [83] ("mindfulness", "watchfulness", and "embeddedness") and in [79] ("openness" and "specificity").

We want to put more emphasis on the left/right distinction: in group C are robots for religion, and they are not "intrinsically religious" objects, such in groups E, F and G. The main factor causing this distinction is their appearance inspired to sacred art and existing cult objects or entities. Sacred art is the term used to indicate art which has have as its theme a sacred subject. Sacred art is defined as artistic imagery with religious inspiration and motifs. It also serves to render the truths expressed in the Holy Scriptures more understandable. Sacred art, however, is not only limited to this role, as the art itself is inherently sacred [84]. Through it, a work of art is a metaphor which can somehow convey the presence of the divine.

Through art techniques and tricks like size, optical illusions and the golden ratio, art can stimulate the senses of

a believer, conveying a divine feeling. One example that involves all these techniques is the frescos on the ceiling of important Catholic churches, which offer an image of "roofs of heaven". This effect is of course subjective, as sacred imagery are inherently sacred to different degrees according to different people; however, art itself can be though as a technical activity that produces an enchantment (the "technology of enchantment" defined in [45]) that may provoke, unsettle or dazzle the spectator.

Common points exist across all religions, where works of art can be found. Through all Asia, art took very different aesthetic forms to express the perfection of the absolute [64]. In Christianity, sacred art is considered dedicated to the ritual service and in Catholicism it has been formalised in the Council of Trent [85]; besides the teaching of moral and spiritual values, the art itself is the experience, as contemplating a beautiful work of art gives a foretaste of contemplating God, who is beauty [86]. The golden ratio has also been intensively used in the Renaissance in many paintings of religious importance. Even through iconoclasm and the lack of depiction of humans it is still possible to encounter the sacred: in Islam, all is clarity and light, and the artist just makes apparent the beauty of all things that come from God (in accordance with the Quran stating that God is beautiful and He loves beauty) [84].

Adding the robotic component to sacred art, or the other way round, designing robots inspired to sacred art, is a challenge that can be taken, as it has its foundations in automata, featuring a combination of divine intervention and theatre, both partners of religion [47].

4 Taxonomies of the Divine and Robots

In order to define the exact meaning of theomorphic robot, we have to have a clearer vision of how humanity represents the divine and how we represent robots.

4.1 Definitions

Before stating, we clarify the terminology related to religion used in the rest of the paper, highlighting the different nuances.

- *Divine*: related to God or a deity, or having a God-like essence and being considered superior. Not strictly referring to the God himself. A divine entity is defined as a living being or an object who has a connection with a deity, be a messenger of the deity, or be possessed by it, or carry a divine essence.
- *Sacred*: belonging to a separate world, related to God or a deity. Typically used in contrast to profane, in reference to actions, objects or spaces. Sacred entities are either present in a sacred place; tracing to a sacred place; belonging to a sacred creature, or universally recognised as sacred.
- *Holy*: dedicated or belonging to God or a deity. Compared to the concept of sacredness, the holy is something that can be attached.
- *Saint*: similar to holy, but typically related to persons, especially in Christianity.
- *Blessed*: made holy, or consecrated through a ritual, or an act of faith and dedication, that confers divine protection.
- *Religious*: related to a religion, intended as a institution that regulated the rules of worship and formulates the theology.

A deity is considered sacred or holy, which is believed to be separated from the profane world, belonging to a superior dimension [27]. Since the essence of a deity is intangible, it acquires different forms.

4.2 Categories of Divine Representations

We report below some example of each category of Fig. 3, clockwise starting from the top:

- *Anthropomorphic gods/holy humans*: this category is common across all religions, as it comes natural for humans to imagine a god as a greater human, and regard persons who came in touch with the divine as holy humans. Examples span from angels to saints, Buddha, Jesus Christ, Krishna and others.
- *Anthropomorphic sacred objects*: any object that represent one of the above mentioned holy humans, or a part of it, features anthropomorphic cues, falls into this category. This includes statues, paintings as well as small objects with some anthropomorphic traits, such as Daruma dolls, common in Buddhism and Shinto.
- *Anthropomorphised sacred animals*: in some religion it is typical to represent some god or divine creature with animals that feature some degree of anthropomorphism, which may vary from the lone ability to speak (Kitsune in Shinto), to being a hybrid creature (Bast in Ancient Egypt; Ganesha in Hinduism).
- *Sacred animals*: the most typical example of this category is the sacred cow of Hinduism. The degree of sacredness varies across religions, from the purely symbolic (the Lion of Judah in Judaism) to the imaginative depiction of a flying reptile deity of Quetzalcoatl (Aztec and Mayan mythology).
- *Zoomorphic sacred objects*: this category is related to the previous, as sacred animals can be portrayed as statues (like Komainu in Shinto) or other small objects (such as Aegis, a shield representing the head of a snaked-haired Gorgon).
- *Hybrid sacred creatures*: any creature that is not anthropomorphised and that is a hybrid with some plant or natural

element belongs to this category. An example of this category is Charybdis, a sea monster of Greek mythology, typically represented as a whirlpool but also having animal features.

- *Sacred objects/symbols*: every religion features a range of objects which sacredness may vary from being just symbolic (a crucifix in Christianity) to being venerated (the Kabah in Islam). Symbols can be are abstract sacred objects: some of them are widely known, such as the Star of David, the Cross, the Crescent, the Om, the Yin-Yang. Sacred writings also fall in this category, although in some cases such as the Bible, the message is sacred, while in others, namely in the case of the Quran, not only the message, but also the words and their calligraphy are sacred. It should be also noted that human conceptualisation of an object or creature may change when it is placed in a different context: e.g. a museum rather than a shrine [87, 88].
- *Physimorphic sacred objects*: this category comprehends objects that represent something sacred in nature, or made by some materials coming from nature. Physimorphic is a generic term deriving from Greek *physi* (nature) and *morphé* (shape): among them, *phytomorphic* (shape of plant) is also possible. A golden plate representing the sun, sacred to the Incas, would fall into this category.
- *Sacred nature*: since pre-history, humanity has begun finding the divine in nature, typically in the sun, present as a god in many ancient cultures, as well as the moon and even the planets (Ancient Greece). This category also includes sacred plants, such as the lotus flower (Buddhism). In many modern religions, plants are just symbolic rather than sacred.
- *Anthropomorphised sacred nature*: when the divine was found in nature, it was also common to assign it some degree of anthropomorphism. Nymphs are a typical example as they are spirits of a tree taking the form of a woman.

Any divine essence that cannot be represented by any of the above categories is considered intangible divine (e.g., the Holy Spirit in Christianity) and therefore is not shown in the taxonomy.

Religion-wise, the contrast between monotheistic religions such as Judaism and Islam, and the polytheistic approach of Hindiusm and Shinto has an impact on the wideness of the divine representation across the categories. While in the latter cases, living beings, objects, and gods are all parts of a whole picture, the ban of idols in monotheistic religions and the strong distinction between the natural and the artificial [89] contribute to make a neater categorisation. Christianity encompasses several divine humans, and actually rather than God being anthropomorphic, humans are theomorphic, since created in the image of God [25]. This concept is even stronger in Islam, where the ban of idols is

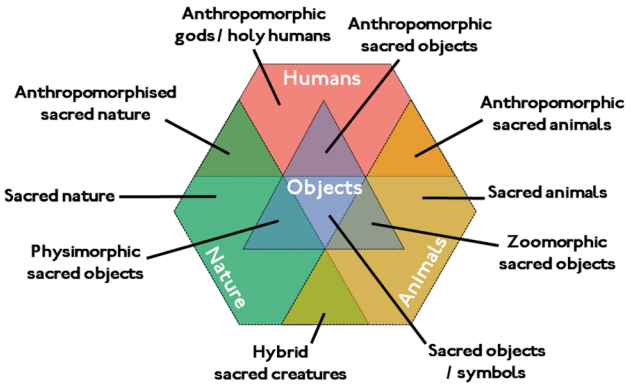

Fig. 3 Categories of representations of the divine

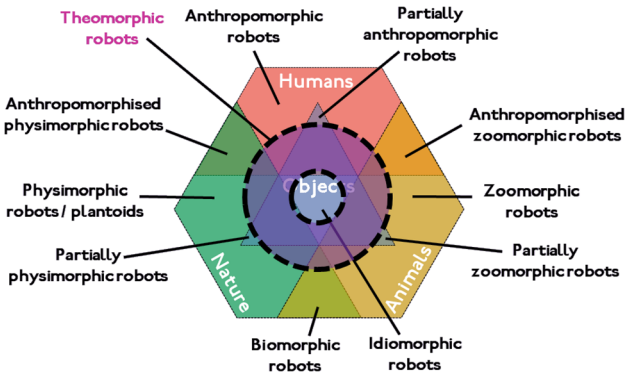

Fig. 4 Categories of robots taxonomy

intended to the extent of forbidding depictions of any human, especially the Prophet, who stands in between a holy human and the intangible divine.

4.3 Categories of Robot Representations

In social robotics, previous research has highlighted three main robot shape categories: anthropomorphic, zoomorphic and functional. All humanoids and robots with anthropomorphic features belong to the first category (from Greek: human (*anthropo*) + shape (*morphé*)); all robots which resemble animals belong to the second (from Greek: animal (*zoo*) + shape (*morphé*)); robots with a functional appearance instead are designed according to their specific purpose.

Correlations between appearance of robots and their application in society were summarised by Li et al. [90]: in that study, anthropomorphic, zoomorphic and functional robots are compared. According to their experimental results, anthropomorphic robots are good for the following uses: public assistance; business; research; and healthcare. Zoomorphic robots are appropriate for the following: security; research; healthcare; education; entertainment. Functional robots are appropriate for: security; public assistance. In an entertainment task, the zoomorphic robot was preferred. The humanlike robot was indicated as most suitable for the secu-

rity guard task and secondarily suitable for the tour guide task; the machine-like robot more for low sociability task as security. Lohse et al. [91] carried out a survey on the same topic. The Android BARTHOC was judged useful for applications of guidance, e.g. receptionist. Zoomorphic robots AIBO and iCat were seen as toys, also useful for healthcare. Functional companion robot BIRON was preferred in fields such as security and services like cleaning.

This taxonomy made of three distinct categories is incomplete, first of all because it does not encompass the cases in between the three categories. Secondly, because there exist a wide number of robots which are inspired to plants and other nature. We propose a new taxonomy for robot design: now, let us analyse the Fig. 4, which describes a taxonomy of robots design that aims to be exhaustive.

- *Anthropomorphic robots*: robots that are made as a shape of humans are typically called humanoids, of which androids are a subclass. KOBIAN-R [73] and Geminoid-F [72] are examples respectively of a mechanical-looking humanoid, and of a realistic android.
- *Partially anthropomorphic robots*: when a robot anthropomorphic features are extremely iconic, it belongs to this category. LG's Hub [92] is a typical example as it is a small social robot with incorporates a screen with two eyes that confer it a social dimension.
- *Anthropomorphised zoomorphic robots*: in this category, zoomorphic robots feature some human traits, such as iCat [93].
- *Zoomorphic robots*: the most famous robot of this category is Sony Aibo [75], with the appearance and behaviour of a dog.
- *Partially zoomorphic robots*: in this category there are robots shaped like objects with some zoomorphic traits. Probo [94] is an example, being an actuated stuffed animal.
- *Idiomorphic robots*: we introduce the term idiomorphic as a more technical term for functional robots. Idio- comes from Greek *ídios* meaning distinct. An idiomorphic robot has distinctive form, such as Roomba [95], the robotic vacuum cleaner.
- *Biomorphic robots*: from Greek *bios* (life), biomorphic robots have a shape inspired to living beings. As this is a generic definition which could include both realms of animals and plants, we use the term in the strict sense of a hybrid shape that is inspired to both nature and animals. Robots of this kind are not common but exist: the six-legged HEXA robot can chase the sun while carrying a plant [96].
- *Partially physimorphic robots*: in this section we can find robots that live in symbiosis with. To illustrate, the Flora robotica project [97] comprehends idiomorphic robots that are part of a ecosystem with plants.
- *Physimorphic robots*: this category of robots carries the shape of something from nature. The sunflower of Himawari Project [74] is a good example. Plantoids is another term for referring to robots inspired by plants [98].
- *Anthropomorphised physimorphic robots*: robots inspired to nature, with anthropomorphic traits are not common. The closest we can find is the Petit Prince [99], which features a plant as well as a human-like single eye.

From this overview, we can conclude that representations of the divine and representation of robots share the same taxonomy. As a consequence, a robot that is associated to something divine can take any of the forms present in the taxonomy. This means adding a new category (in purple in Fig. 4) overlapping all the previous ones.

4.4 Theomorphic Robots Category

In Fig. 5, we place some robots from Fig. 2, together with examples mentioned in the previous section, into the complete taxonomy of robot design. Among robots related to religion, it is possible to notice in:

- *Anthropomorphic robots (non-theomorphic)*: BlessU-2 and Xi'aner.
- *Anthropomorphic robots (theomorphic)*: The devil automaton and the mechanical monk.
- *Partially anthropomorphic robots (theomorphic)*: DarumaTO-2 and SanTO.
- *Idiomorphic robots (theomorphic)*: Hero's altar to Dionysus.

Not all of the categories necessarily make sense in terms of making meaningful theomorphic robots. In particular, the

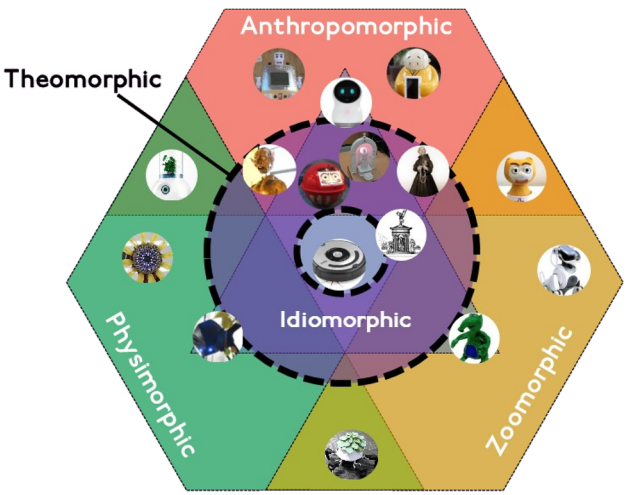

Fig. 5 Placement of robots in each category of robots taxonomy. The theomorphic overlaps all the other categories

utility of making a theomorphic robot depends on the specific religion and the connotations that a deity has.

Certain categories may also be more appropriate than others. In the case of humanoids, slight differences from humanness typically can trigger an uncanny effect. Likewise, anthropomorphic deities can also be disturbing while arousing fear and fascination [25]. Zoomorphic and physimorphic robots are possible, although some additional context will be necessary to clarify the theomorphic identity. Idiomorphic robots are easier to create due to the lack of constraints in the similarity of appearance compared to a living being.

4.5 Purpose of Theomorphic Robots

We argue that the impression that theomorphic robots may have some advantages over non-theomorphic ones, for certain applications.

4.5.1 Acceptance

A theomorphic robot may be accepted more favourably than a non-theomorphic robot. This hypothesis is related to the fact that religion is intertwined with culture, and divine representations are present in world culture and are familiar especially to believers, but also not non-believers. This concept is an extension of the core concept of culturally-aware robotics.

4.5.2 Comfort

The fact that a theomorphic robot is connected with some divine or has some supernatural capabilities may make the user feel protected by the robot.

4.5.3 Regard

For a believer, the perception of sacredness makes a difference in the regard held towards objects and living beings. In the same way as a copy of the Quran is held in high regard compared to a common book, especially by believers but not limited to them, a theomorphic robot can be held in high regard.

Points 1 and 2 correspond exactly to the reasons, mentioned in the introduction, of the importance of religion in robotics. Points 2 and 3 concur together as a biunivocal positive effect between the user and the robot. The user, recognising the protective role and the superhuman capabilities, may feel safer thanks to the robot. At the same time, the robot itself may be taken in higher consideration and respect, to another degree compared to the simple politeness highlighted in the experiments described in The Media Equation [100].

The segments of users which can benefit from theomorphic robots should also be discussed. We identified the following groups:

- Elderly people: in many countries, elderly people are more emotionally attached to religion, culture and local folklore. In addition, their possible impairment with new technologies, which can be caused by a number of factors including cultural issues, can be overcome by using an "enhanced" robotic version of a familiar object.
- Children: robots could be used in educational environments to attract the attention of students to learn about religion as well as history topics. An experiment of this kind was carried out in Peru to study Inca culture using Robovie V [101].
- Any other segment of population for which it is easier to obtain suspension of disbelief. One example could be illiterates, who are not able to use technologies, but may still be well aware of local traditions and folklore. In their case, previous research suggested that their condition may prompt a greater suspension of disbelief in human–robot interaction [102].

5 Design Guidelines for Theomorphic Robots

As stated in [62], "paying attention to religion and religious practices forces us to move beyond efficiency as a useful metric for measuring technology success". We believe that perceived sacredness is a key factor in the creation of theomorphic robots.

The design question is: how to project sacredness into a robot? As a preliminary remark, we must mention that the perceived sacredness is highly subjective. It can depend on the faith of the person, on the degree of religiosity and spirituality (which is a difficult factor to measure), and on the tendency to need some physical object for supporting one's own faith as opposed to a more abstract view, closer to iconoclasm.

Regarding the robot itself, several factors can give or take away, resulting in different shades of sacredness. Although difficult to measure experimentally, we offer here some concrete guidelines for enhancing the sacredness of a theomorphic robot. Before introducing the 10 guideline points, we discuss about relevant issues in the following subsections.

5.1 Robot-Likeness

According to McCloud's design space [103] applied to robots [104, 105], robots can be designed by following different strategies and can result in looking more or less realistic, or iconic, or abstract. Realism is given by the resemblance to an

existing entity and the complete concealment of the robotic element.

This distinction may apply to any robot in each category of our taxonomy. In case of anthropomorphic robots, androids such as Geminoid-F is made pursuing anthropomorphism without constraints, and is equivalent to the bottom-left vertex of McCloud's design space. On the other hand, the humanoid KOBIAN-R does not conceal the robotic element. LG's Hub, a partially anthropomorphic robot, that incorporates a screen with two eyes, corresponds to the bottom-right corner of McClouds's design space: the "iconic" robots rely only on a very stylised set of human features. The same distinction exists for zoomorphic robots (compare the realistic Paro [106] with Aibo); physimorphic (compare the rather realistic sunflower with the plantoid); and idiomorphic (compare Guy Hoffman's AUR Robotic Desk lamp [107], which "retains the lamp's objectness", or even self-driving cars, also loosely fitting in this category, with the Roomba). In the intersections between the categories, similar examples can be found.

When this distinction is applied to theomorphic robots, the question of the pros and cons of robot-likeness becomes relevant. We hypothesise that a visible robotic element is less suitable, as it makes more difficult to appear a credible representation of the divine. This perception, however, is highly subjective and dependent on the context: the mechanical monk, along with other automata employed in religion used to provoke amazement, but could hardly be believed supernatural nowadays.

5.2 Skeuomorphism

Without having a final answer to previous research question, we mention the concept of skeuomorphism, which is relevant regardless of the answer. The term skeuomorph comes from Greek *skéuos* (container or tool) and *morphḗ* (shape). It refers to an object that is designed in a way to retain design inherent to another already existing object [108]. A typical example can be found in computer graphical interface, as Apple introduced a GUI that drew a visual metaphor between new concepts and familiar objects (files, trash bin, etc.).

In these regards, 'affordance' is also a key concept for designers who want to build products that are intuitive and easy to use. This process is a form of cultural heritage [109], as it is easier for those familiar with the original object to use the digital emulation by making certain affordances stronger, and after getting accustomed to a process, it persists in a culture. The mechanism of affordances has been confirmed by researchers in neurophysiology as brain imaging have reported evidence of neural activity [110]. Hence, the subconscious perception of a familiar form is a mechanism that has consequences in robotics, both for the development of their cognitive skills and for their appearance.

Generally speaking, hiding the robotic element can make the visual association with the previously existing object/living being explicit. More mechanical looking robots, can recall existing shapes, however the loose association requires some reasoning and cannot be categorised as an affordance.

Theomorphic robots are a special case. This is because skeuomorphism is applied to sacred art and symbols of theology. The importance of symbols makes the visual association and affordance easier. At the same time, the need of incorporating symbols and abstract concepts while representing the divine implies that for theomorphic robots, skeuomorphism is a necessity.

5.3 Infallibility

This point is a very critical one: how to deal with a robot that may realistically fail, whereas the divine implies infallibility. While it is important to limit failures whenever possible, this issue is one of no easy solution. We should remind the distinction between the divine itself and a tool that, like any other existing representation of the divine, may be broken or killed.

5.4 Practical Guidelines

5.4.1 Identity

A theomorphic robot shall not mean impersonating a deity with the purpose of deceiving or manipulating the user. The robot will still be a tool on which the divine is projected and can possibly act as intermediary with the divine, like any other already existing sacred object: it will be identified just as its "enhanced version". Being a tool, identity does not mean that the robot has to be treated like an individual. From the point of view of legislation, the robot is still to be considered an object of law, therefore subject of legal regulation, although its religious identity may imply that it is also subject to some kind of religious law.

5.4.2 Naming Issues

In line with the principles of hiding the robotic element and of skeuomorphism, the name with which the robot is introduced to the user should be defined in a way that conceals any reference to a robot. Example: a theomorphic robot resembling a hypothethic object/creature X of a given religion should retain its technical name of a 'Robotic X' only in the context of its development, whereas it should be introduced to a user as 'X' or as an enhanced version of X, and it should introduce itself as such.

5.4.3 Symbology

In order to represent the divine, the study of the field of symbology is critical. Sacred symbols can be intended as abstract sacred objects: some of them are widely known, such as the Star of David or the Crescent. Symbols sometimes can be valid across religions. Christianity as well has borrowed from the group of significant symbols known to most periods and to many regions of the world [111].

A sacred symbol can make people hold in higher regards an object, a person, a location, or even feel safe thanks to it [112], hence, the protective role that can come to a user from a theomorphic robot. The protective role is amplified by the fact that the robot may have capabilities that humans do not have (such as infrared sensors).

From a design point of view, it is critical to follow artisans' art conventions in sacred art in order to give the same visual representation. The importance of following conventional usage in the choice of images is underlined in the principles listed in [109] regarding cultural constraints and conventions.

5.4.4 Blessing

Symbolism, rather that visually represented, can even be conferred by religious authorities: this would be the case of a robot being blessed by the official church. A ritual can confer the sacredness or the holiness, causing additional legitimacy to the robot.

5.4.5 Materials

The materials of which the robot is made may play a role in a believer's perception. A precious material linked, for instance, to a sacred place, or a relic, while having no intrinsic value for a non-believer, are of an extraordinary worth in a context of belief [113].

5.4.6 Context

Sacred places range from an earthly place of importance to a site associated with divinity. In the latter case, they are locations where interaction between human and divine took place, or where higher powers revealed themselves to people, or where interactions between the human and spiritual realms commonly happen [114]. Sacred objects are sometimes present or traced to such places. While they are universally recognised as sacred, conversely the perception may change when the object is placed in a different context: e.g. a museum rather than a shrine [87, 88]. Therefore, it is important to ensure that the robot is employed in a location that does not alter the perception of the sacred or divine it represents.

5.4.7 Movement

In a robot, a lack of human-like features can effectively enhance, rather than impede, social interaction in some specific circumstances. These circumstances happen in human–god interaction as described by Vidal [26] when a deity can manifest itself without a coherence of behaviour and without displaying superhuman capability. The channel used by the deity to communicate, in case of Vidal's example on Hinduism, is a medium, whose erratic behaviour makes him/her a subhuman, or in Haslam's sense, a non-human, rather than a superhuman. Then, it is up to human acknowledgment to give a sense to the interaction. Believers do not expect a human-like communication, and give their own interpretation to a sub-human behaviour or to even a total absence of reaction. Therefore, contrary to the common beliefs of roboticists, the aim of creating a social interaction can be successful even without building a robot whose behaviour is close to human, given the right circumstances that create a suspension of disbelief. The attribution of divine features to a robot may make this circumstance.

Likewise, non-logical conversation topics like mysticism can help overcome the required logical consistency of a dialogue between a human and a robot. With the goal of passing the Turing Test, this was the attempt of the Moai-looking "Mysterious Machines" in [115].

Representing the divine in a robot can therefore lower the expectations of the user in terms of human-like response. Conversely, we hypothesise that an excessive human-like communication capability, and especially movement, can take away this suspension of disbelief, and make the robot clearly appear as a product or a toy. In conclusion, regarding movement and human-like communicative features, less is more.

5.4.8 User Control

For this point, the same conclusion drawn on movement can be applied. User control, while generally seen as an important feature for human–robot interaction, can be a drawback in theomorphic robots as they may take away the suspension of disbelief. Buttons, keyboards, and touch screens can give the idea of a human-made product: restrictions should be applied. A similar consideration can be done regarding powering the robot, as the necessity of a constant user input, for example for the exchange of batteries may be drawbacks.

A possible strategy in this case can be differentiation: if the robot is composed by different parts, the power controls can be stored in one part, leaving the other, more symbolic one, apparently unrelated to mundane issues.

5.4.9 Use of Light

With restrictions on movement and interface, other ways of communication become more important, such as voice and lights.

In many religions of the world, since Manichaeism and even in Maya culture, light has always been associated to divine presence, in contrast to the darkness (lack of light), in dualism good–evil [116, 117]. This fact has influenced the aesthetic codes in sacred art as well as popular culture.

The supposed ability of a deity or angels to express themselves communicatively through light, rather than through physically human capabilities can therefore be implanted into a theomorphic robot, which can communicate with lights as opposed to more human-like communication means.

5.4.10 Use of Touch

Symbols can involve a sensorial experience, because of the importance of getting in physical touch with those symbols for a believer. The holiness is contagious, as touching a sacred object, a statue of a saint, or a living holy human is believed to grant protection [118]. Likewise human–god interaction, in theomorphic robot design touch sensors are an important mean of communication, and their location should be planned according to the specific morphology.

6 First Prototypes

In this section we introduce two recently developed theomorphic robots, and some preliminary feedback and issues.

6.1 DarumaTO-2

Daruma dolls are common in Japan as talismans of good luck, modelled after Bodhidharma, founder of a sect of Buddhism. Darumas are said to bring good luck in a variety of occasions. The custom is to paint a black circle in Daruma's right eye at the beginning, while fixing a goal: Daruma will keep that eye on that goal. Daruma's eyes are both white (which means closed) at the beginning. At the accomplishment of the goal, the other eye is painted black, therefore having both eyes open [119].

Given its positive connotations, and the widespread use in all Japan for its common usage, particularly among older generations, a robotic Daruma can have an application in a nursery home or in general can support elderly people.

In this role, a robotic Daruma, if provided of interaction (including speech) capabilities, would also have some advantages over other robots used for elderly care. This includes seal robot Paro, which not being able to speak, has a limited range of interaction, and dog robot Aibo, which robotic appearance may be distressing at the first approach.

DarumaTO-2 is the second prototype to be developed, and it is partially anthropomorphic, with robotic component revealed. Preliminary qualitative investigations, carried out through interviews to Japanese elderly people and nursery homes managers shown that although the elderly are often hindered in the use of mobile phone, technological devices, and may feel distress at the idea of interaction with new devices such as robots, they seem to be comfortable with the idea of a "talking Daruma", as long as the word robot is not mentioned.

The empirical development of the robot and its test applications were also useful to determine the design guidelines we are presenting in this paper.

6.2 SanTO

SanTO is a theomorphic robot having the shape of a statue of a Christian Catholic saint inside a niche. It is fully described in [82]. The design guidelines were followed in the creation of this partially anthropomorphic robot with robotic element hidden. In particular, skeuomorphism was intensively used in symbology (the posture of the arms of the saint, the presence of the cross and the reference to sacred art) and in communication modes (touch, light, interaction mode, and voice reverb).

SanTO is intended to be a prayer companion for Catholics: it can contain a database of prayers and give pertinent answers by citing sacred texts. In Europe, in countries like Italy and Spain, the ideal intended user is a practicant elderly. In Latin America, SanTO can be of more general purpose. This is because of the presence, deriving from customs related to pre-hispanic gods, to the presence of a "sacred idol" in every house or in a personal altar. People usually pray to the saints (who were humans) and the saints pray to God.

6.3 Ethical Debates

The idea of involving religion into robots has been criticised from the beginning, both from conservative believers, who believe that religion is taboo, from people with iconoclast mindset, believing that representation of the divine is taboo, and from anti-clericals, who believe that science should eradicate religion. Other views are very subjective, as those who cannot see any sacredness in the original cult object, fail to see the sacredness of the robot too.

The most sensed criticism involved the possibility of using the robot to impersonate a deity or to manipulate believers through deception. However, the actuation of a religious object is not intrinsically implying deception. In some occasions happening even nowadays, such as the Holy Week celebrated in Ayacucho (Peru) or the procession of Pozza-

llo (Sicily, Italy), events with actuated statues take place. In the latter, human-operated statues of the Virgin Mary and Jesus Christ move their arms and finally embrace, in front of thousands of believers, who even knowing that there is nothing supernatural in the actuation, still feel the emotion of the performance. The development of the robotic Daruma in a nursery home has not raised ethical debates so far, despite the potential issues regarding deception. In these cases, we believe that nudging users to do certain actions is ethically good as long as it is done for their own health, as proposed in IEEE Ethically Aligned Design guidelines [120].

We believe that the ethical problem should not be a burden for the researchers as long as the use of technology for a good cause does not go against the legitimate institutions entitled to judge theological issues (in the case of SanTO, the Catholic Church) and as long as it is following an ethical robot design such as proposed by IEEE [120]. The official response from the CEI (Episcopal Conference of Italy) regarding SanTO was cautious: the Church stand in a positive stance towards the use of technology for a good cause, however warning about the complexity of the interpretation of Biblical passages.

Within the Church, there are also different views on these topics. Specifically regarding SanTO, but also applicable to other theomorphic robots that have the same function, it is reasonable to think that the progressivists will be more welcoming towards technological innovation in faith, while conservatives will keep a more negative stance. However, this may be far from the truth. Conservatives in a religion based on established rituals tend to support the keeping of the status quo: the religious institution works as long as believers follow and pray. A robot that repeats some ritual ends up into strengthening the devotional line, and can become a powerful tool for conservatives. Conversely, progressivists wish that believers think by themselves and get educated. For this reason, rather than a robot that repeats some answers, they might prefer a robot that poses questions.

6.4 Open Challenges

A few open challenges emerge from these considerations:

- Find the best uses of each theomorphic robot, provided that it can be more than strictly religious use. Associated to the use, the target user segment has also to be determined.
- Measure the sacredness of theomorphic robots in comparison with existing cult objects. Due to the highly subjective nature of this perception, finding the underlying factors may be a challenging task.
- Empirically confirm the validity of the design guidelines.
- Determine the best configuration regarding movement. This is an important issue in particular for the robotic saint, as typically saints are perceived as a still image (motionless) were people can project their personal ideals of a good person, a master or a protector. The only "moving saint" in Catholicism is the one that comes in procession, precisely because it is being carried by people as a way of tribute, which is therefore associated with a human interaction, for example during praying, or cult.

7 Conclusion

This paper analysed the state of the art of the relations between two distant worlds: robots and religion. While typically seen in opposition, the two worlds have actually a significant possibility of bringing benefit to each other. Given the long history of intertwinings and the present state of the art, robots (and more generically, technology and automation) in religion can be broadly categorised as "for religion" and "theomorphic". A novel taxonomy of robots design was proposed to be comprehensive of anthropomorphic, zoomorphic, physimorphic, idiomorphic and theomorphic robots. We presented ten concrete guidelines for conveying the divine and realising a theomorphic robot. Finally, two examples were presented, initiating the discussion on ethics and further needs of experimental evidence.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Besancon A (2000) The forbidden image: an intellectual history of iconoclasm. University of Chicago Press, Chicago
2. Yerxa DA (2015) Religion and innovation: antagonists or partners?. Bloomsbury Academic, London
3. Dianich S (1987) Chiesa in missione. Per un'ecclesiologia dinamica (in Italian), San Paolo Edizioni
4. Bell G (2006) No more SMS from Jesus: ubicomp, religion and techno-spiritual practices. In: UbiComp 2006: ubiquitous computing, pp 141–158
5. Muller MJ, Christiansen E, Nardi B, Dray S (2001) Spiritual life and information technology. Commun ACM 44(3):82–83
6. Kimura T (2017) Robotics and AI in the sociology of religion: a human in imago roboticae. Soc Compass 64(1):6–22
7. Duffy BR (2003) Anthropomorphism and the social robot. Robot Auton Syst 42(3–4):177–190
8. Tondu B (2012) Anthropomorphism and service humanoid robots: an ambiguous relationship. Ind Robot Int J 39:609–618
9. Weiss A, Evers V (2011) Exploring cultural factors in human-robot interaction: a matter of personality?. Presented at the 2nd International Workshop on Comparative Informatics, IWCI 2011, Denmark
10. Nomura T et al (2008) What people assume about humanoid and animal-type robots: cross-cultural analysis between Japan, Korea, and the United States. Int J Hum Robot 05(01):25–46

11. Trovato G et al (2013) Towards culture-specific robot customisation: a study on greeting interaction with Egyptians. Presented at the The 22nd IEEE international symposium on robot and human interactive communication (ROMAN 2013), Gueongju, South Korea
12. Trovato G, Ham JRC, Hashimoto K, et al (2015) Investigating the effect of relative cultural distance on the acceptance of robots. In: Social robotics. Springer, Cham, pp 664–673
13. Trovato G, Eyssel F (2017) Mind attribution to androids: a comparative study with Italian and Japanese adolescents. In: 2017 26th IEEE international symposium on robot and human interactive communication (RO-MAN), pp 561–566
14. Arras KO, Cerqui D (2005) Do we want to share our lives and bodies with robots? A 2000 people survey. Technical Report Nr. 0605-001, Autonomous Systems Lab, Swiss Federal Institute of Technology Lausanne (EPFL)
15. Geraci RM (2006) Spiritual robots: religion and our scientific view of the natural world. Theol Sci 4(3):229–246
16. Russell B (2017) Robots: the 500-year quest to make machines human. Scala Arts & Heritage Publishers Ltd, London
17. Taube KA (2012) Creation and cosmology. In: The Oxford handbook of mesoamerican archaeology
18. The Pew Forum on Religion & Public Life (2012) The Global Religious Landscape. Pew Research center. https://www.pewforum.org/global-religious-landscape.aspx
19. Hill P, Pargament KI (2003) Advances in the conceptualization and measurement of religion and spirituality. Implications for physical and mental health research. Am Psychol 58:64–74
20. Okpaku SO (1998) Clinical methods in transcultural psychiatry. American Psychiatric Pub, Philadelphia
21. Smith A (2014) Older adults and technology use. Internet, Science & Tech, Pew Research Center, Washington
22. European Commission (2012) Public attitudes towards robots. Special Eurobarometer 382
23. McIntyre AJ (1979) Romantic transcendence and the robot in Heinrich Von Kleist and E.T.A. Hoffmann. Ger Rev Lit Cult Theory 54(1):29–34
24. Foerst A (1998) Cog, a humanoid robot, and the question of the image of god. Zygon 33(1):91–111
25. Higgins RS (2013) Of gods and monsters: supernatural beings in the uncanny valley. Annual meeting of the European association for biblical studies. Leipzig, Germany
26. Vidal D (2007) Anthropomorphism or sub-anthropomorphism? An anthropological approach to gods and robots. J Roy Anthropol Inst 13:917–933
27. Durkheim É (1915) The elementary forms of the religious life. G. Allen & Unwin, London
28. Geraci RM (2007) Robots and the sacred in science and science fiction: theological implications of artificial intelligence. Zygon 42(4):961–980
29. Foerst A (2005) God in the machine: what robots teach us about humanity and god. Plume
30. Lindstrom L (1993) Cargo cult: strange stories of desire from melanesia and beyond. Univ of Hawaii Pr, Honolulu
31. Asimov I (1951) I, Robot. Gnome Press, New York
32. Adler MJ (1993) The Angels and Us. Paperback
33. Haslam N (2006) Dehumanization: an integrative review. Pers Soc Psychol Rev 10(3):252–264
34. Haslam N, Kashima Y, Loughnan S, Shi J, Suitner C (2008) Subhuman, inhuman, and superhuman: contrasting humans with nonhumans in three cultures. Soc Cognit 26(2):248–258
35. Trovato G, Cuellar F, Nishimura M (2016) Introducing "theomorphic robots". In: 2016 IEEE-RAS 16th international conference on humanoid robots (Humanoids), pp 1245–1250
36. Trovato G, Lucho C, Huerta-Mercado A, Cuellar F (2018) Design strategies for representing the divine in robots. In: Companion of the 2018 ACM/IEEE international conference on human–robot interaction, New York, NY, USA, pp 29–35
37. Grant M, Hazel J (2002) Who's who in classical mythology. Psychology Press, New York
38. Nelson V (2009) The secret life of puppets. Harvard University Press, Cambridge
39. Chapuis A, Droz E (1958) Automata: a historical and technological study. Neuchâtel: Editions du Griffon, London
40. Tybjerg K (2003) Wonder-making and philosophical wonder in Hero of Alexandria. Stud Hist Philos Sci Part A 34(3):443–466
41. Herodotus, Godley AD (1921) Herodotus. With an English translation by AD Godley. Heinemann, London
42. Mikalson JD (2004) Herodotus and religion in the Persian wars. Univ of North Carolina Press, Chapel Hill, p 2004
43. Ghosh S, Banerjee UK (2006) Indian puppets. Abhinav Publications, New Delhi
44. Riskin J (2016) The restless clock: a history of the centuries-long argument over what makes living things tick. University of Chicago Press, Chicago
45. Gell A (1994) The technology of enchantment and the enchantment of technology. In: Coote J (ed) Anthropology, art, and aesthetics. Clarendon Press, Oxford
46. Riskin J (2012) Machines in the garden. In: Biagioli M, Riskin J (eds) Nature engaged. Palgrave Macmillan US, Washington, pp 229–248
47. King E (2002) Clockwork prayer: a sixteenth-century mechanical monk. Blackbird 1(1):1–29
48. Soós K, Rácz J (1990) Eine Automatenfigur in Budapest (in German "An automaton figure in Budapest). Z Kunsttechnol Konserv 4:207–214
49. Saif M (2006) The evolution of persian thought regarding art and figural representation in secular and religious life after the coming of Islam. Macalester Islam J 1(2):6
50. Thomas RM (1987) Computer technology: an example of decision-making in technology transfer. In: Thomas RM, Kobayashi VN (eds) Educational technology—its creation, development and cross-cultural transfer. Pergamum Press, Oxford, pp 25–34
51. Rogers EM (2003) Diffusion of innovations, 5th edn. Free Press, London
52. Sharif J (1921) Islam in India or the Qanun I Islam. Oriental Book Reprint Corporation, New Delhi
53. Speziale F (2007) Il simbolismo mistico del volto umano nel trattato (in urdu) Sūrat-i ma'lūma-yi ṣuwari'ilm di Karīm Allāh'Āshiq (in Italian). J Asiatique 295(2):439–459
54. Brittlebank K (1995) Sakti and Barakat: the power of Tipu's tiger. An examination of the tiger emblem of Tipu Sultan of Mysore. Mod Asian Stud 29(2):257–269
55. Riek L et al (2010) Ibn Sina steps out: exploring Arabic attitudes toward humanoid robots. In: Proceedings of the 2nd international symposium on new frontiers in human–robot interaction, vol 1. AISB, Leicester
56. Vālmīki (1981) The Yoga-vásishtha-maháramáyana of Válmiki. Bonnerjee and Company
57. Debroy B (2015) The Mahabharata: complete and unabridged, 2015th edn. Penguin Books India Pvt. Ltd., New Delhi
58. Ganapati Bappachi Robotic Aarti. Robolab Technologies Pvt Ltd. [Online].https://www.robolab.in/ganapati-bappachi-robotic-aarti/. Accessed 04 Feb 2019
59. Grimaud E (2008) Dieux & robots: Les théâtres d'automates divins de Bombay (in French). L'Archange Minotaure, Apt
60. Kaplan F (2004) Who is afraid of the humanoid? Investigating cultural differences in the acceptance of robots. Int J Hum Robot 01(03):465–480

61. Idel M (1990) Golem: Jewish Magical and Mystical Traditions on the Artificial Anthropoid. State University of New York Press, Albany
62. Woodruff A, Augustin S, Foucault B (2007) Sabbath day home automation: "It's Like Mixing Technology and Religion". In: Proceedings of the SIGCHI conference on human factors in computing systems, New York, NY, USA, pp 527–536
63. Dundes A (2002) The shabbat elevator and other sabbath subterfuges: an unorthodox essay on circumventing custom and Jewish character. Rowman & Littlefield Publishers, Lanham
64. Okakura K (2012) The ideals of the east. Jazzybee Verlag, Loschberg
65. Mori M (1989) The Buddha in the robot. Kosei Publishing Company, Tokyo
66. Currell D (2015) Shadow puppets and shadow play. Crowood, Marlborough
67. Schodt FL (1988) Inside the Robot Kingdom - Japan, Mechatronics, and Coming Robotopia. Kodansha, Tokyo
68. Yamaguchi M (2005) 'Karakuri: the ludic relationship between man and machine in Tokugawa Japan', in Japan at Play. Routledge, London
69. Takanishi A (2011) Humanoid robots, and the culture and history of the Japanese people. Acta Philos 20(1):29–52
70. NISSEI ECO. Pepper Funeral Homes & Cremation Facility, Inc. | Canton PA funeral home and cremation. *Pepper Funeral Homes & Cremation Facility, Inc. | Canton PA funeral home and cremation*. https://www.PepperFuneralHomes.com/. Accessed 22 Aug 2018
71. Uriu D, Odom W, Gould H (2018) Understanding automatic conveyor-belt columbaria: emerging sites of interactive memorialization in Japan. In: Proceedings of the 2018 designing interactive systems conference, New York, NY, USA, pp 747–752
72. Nishio S, Ishiguro H, Hagita N (2007) Geminoid: teleoperated android of an existing person. In: Humanoid robots: new developments. Armando Carlos de Pina Filho. InTech, Vienna, Austria, pp 582–591
73. Trovato G, Zecca M, Kishi T, Endo N, Hashimoto K, Takanishi A (2013) Generation of humanoid robot's facial expressions for context-aware communication. Int J Hum Robot 10(01):1350013
74. Nakayasu A, Tomimatsu K (2009) Himawari plant robot: creature expression using shape-memory-alloy actuator crowd robots. In: ACM SIGGRAPH ASIA 2009 art gallery and emerging technologies: adaptation, New York, NY, USA, pp 72–72
75. 'aibo', aibo. http://aibo.com/. Accessed 22 Aug 2018
76. 'The Source for X10 & X10 Pro Genuine Products'. https://www.x10.com/. Accessed 22 Aug 2018
77. Sherwood H (2017) Robot priest unveiled in Germany to mark 500 years since Reformation. *The Guardian*, 30-May-2017
78. 'Robot monk blends science and Buddhism at Chinese temple', Reuters, 22 Apr 2016
79. Gaver W, Blythe M, Boucher A, Jarvis N, Bowers J, Wright P (2010) The prayer companion: openness and specificity, materiality and spirituality. New York, NY, USA, pp 2055–2064
80. Atheist F, Must-SEE: iranian robot, constructed by Qur'an teacher, instructs Muslim children how to pray. Friendly Atheist
81. Jds. COSMODROMIUM: Mechanical Devils. COSMODROMIUM, 21 Apr 2011
82. Trovato G, Lucho C, Ramon A, Ramirez R, Rodriguez L, Cuellar F (2018) The creation of SanTO: a robot with "divine" features. Presented at the 15th international conference on ubiquitous robots, Honululu, USA
83. Wyche SP, Aoki PM, Grinter RE (2008) Re-placing faith: reconsidering the secular-religious use divide in the United States and Kenya. In: Proceedings of the SIGCHI conference on human factors in computing systems, New York, NY, USA, pp 11–20
84. Burckhardt T (1967) Sacred art in east and west: its principles and methods. Airlift
85. Council of Trent (1563) De Invocatione, veneration et reliquiis sanctorum, et de sacris imaginibus, vol 2. Norman P. Tanner, London
86. Lopez Pinto A (2014) Common sense approach to the restoration of sacred art. Studia Gilsoniana 3:537–545
87. Leonard SA, McClure M (2003) Myth and knowing: an introduction to world mythology, 1st edn. McGraw-Hill Education, Boston
88. Rosenberg D (1994) World mythology, 2nd edn. McGraw-Hill Education, Lincolnwood
89. Latour B (1991) Nous n'avons jamais été modernes (La découverte). English translation revised and augmented: We Have Never Been Modern, Simon and Schuster. 31 England and Harvard University Press
90. Li D, Rau PLP, Li Y (2010) A cross-cultural study: effect of robot appearance and task. Int J Soc Robot 2(2):175–186
91. Lohse M, Hegel F, Swadzba A, Rohlfing K, Wachsmuth S, Wrede B (2007) What can I do for you? Appearance and application of robots. In: Workshop on the reign of catz and dogz? The role of virtual creatures in a computerised society
92. 'LG's new Hub Robot can integrate all your home appliances'. CNET. https://www.cnet.com/reviews/lg-hub-robot-preview/. Accessed 19 Aug 2018
93. van Breemen A, Yan X, Meerbeek B (2005) iCat: an animated user-interface robot with personality. In: Proceedings of the fourth international joint conference on autonomous agents and multiagent systems, New York, NY, USA, pp 143–144
94. Saldien J, Goris K, Yilmazyildiz S, Verhelst W, Lefeber D (2008) On the design of the huggable robot probo. J Phys Agents 2(2):3–12
95. Roomba Robot Vacuum | iRobot. https://www.irobot.com/For-the-Home/Vacuuming/Roomba/. Accessed 22 Aug 2018
96. HEXA the six-legged robot plant chases the sun to look after its succulent. designboom | architecture & design magazine, 13-Jul-2018. https://www.designboom.com/technology/hexa-robot-plant-vincross-succulent-07-13-2018/. Accessed 22 Aug 2018
97. Hamann H et al. (2017) Flora robotica: an architectural system combining living natural plants and distributed robots. arXiv:1709.04291 [cs]
98. Mazzolai B, Laschi C, Dario P, Mugnai S, Mancuso S (2010) The plant as a biomechatronic system. Plant Signal Behav 5(2):90–93
99. Le Petit Prince—the Cute Little Gardener Meant for Mars (w/Video). https://phys.org/news/2009-09-le-petit-prince-cute.html. Accessed 22 Aug 2018
100. Reeves B, Nass C (1996) The media equation: how people treat computers, television, and new media like real people and places. Cambridge University Press, Cambridge
101. Cuéllar FF, Peñaloza CI, López JA (2016) Educational robots as promotors of cultural development. In: The eleventh ACM/IEEE international conference on human robot interaction, Piscataway, NJ, USA pp 547–547
102. Trovato G et al (2015) "Olá, my name is Ana": a study on Brazilians interacting with a receptionist robot. Presented at the the 17th international conference on advanced robotics, Istanbul, Turkey
103. McCloud S (1994) Understanding comics: the invisible art, Reprint edn. William Morrow Paperbacks, New York
104. Blow M, Dautenhahn K, Appleby A, Nehaniv CL, Lee D (2006) The art of designing robot faces: dimensions for human–robot interaction. In: Proceedings of the 1st ACM SIGCHI/SIGART conference on human–robot interaction, New York, NY, USA, pp 331–332
105. Wodehouse AJ, Ion WJ (2010) Information use in conceptual design: existing taxonomies and new approaches. Int J Des 4(3):53–65

106. Shibata T, Wada K, Tanie K (2004) Tabulation and analysis of questionnaire results of subjective evaluation of seal robot in Japan, U.K., Sweden and Italy. In: 2004 IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA'04, 2004, vol 2, pp 1387–1392
107. AUR Robotic Desk Lamp « Guy Hoffman. http://guyhoffman.com/aur-robotic-desk-lamp/. Accessed 09 Jul 2018
108. Basalla G (1988) The evolution of technology. Cambridge University Press, Cambridge
109. Kaptelinin V (2014) Affordances and design. The Interaction Design Foundation, Copenhagen
110. Jamone L et al (2017) Affordances in psychology, neuroscience and robotics: a survey. IEEE Trans Cognit Dev Syst PP(99), 1–1
111. Rajput SA (2016) The source, meanings and use of "mudra" across religions. Int J Comput Res Dev 1(1):36–41
112. Marzal M (1976) Diez hipótesis de interpretación del catolicismo popular (Ten hypotheses of interpretation of popular Catholicism), Sígueme
113. Renfrew C (2008) Neuroscience, evolution and the sapient paradox: the factuality of value and of the sacred. Philos Trans R Soc Lond B Biol Sci 363(1499):2041–2047
114. Deloria V (1999) Spirit and Reason: The Vine Deloria, Jr. Reader. Fulcrum Publishing, Golden
115. Schonenberg B, Bartneck C (2010) Mysterious machines. Piscataway, NJ, USA, pp 349–350
116. Watson B (2016) Light: a radiant history from creation to the quantum age. Bloomsbury Publishing, New York
117. Ferguson G, Ferguson GW (1959) Signs and symbols in Christian art. Oxford University Press, Oxford
118. Douglas M (2003) Purity and danger: an analysis of concepts of pollution and taboo. Psychology Press, London
119. Greer MA (2002) Daruma eyes: the sixth century founder of Zen Buddhism and Kung Fu had the earliest recorded Graves' ophthalmopathy. Thyroid 12(5):389–391
120. IEEE Standards Association. Ethically Aligned Design, Version 2 (EADv2) 2018

Gabriele Trovato is currently Assistant Professor in Waseda University, Tokyo, Japan. He graduated in Computer Engineering in the University of Pisa, Italy, and got Ph.D. degree in Biorobotics in Waseda University. Within the relations between the two countries, Gabriele Trovato has been in the organising committee of Italy-Japan Workshops since 2011. He has been Visiting Researcher in Karlsruhe Institute of Technology (Germany), Carnegie Mellon University (USA), University of Sao Paulo (Brazil), PUCP (Peru) and Imperial College London (UK) among others. Gabriele Trovato has worked in the video game industry, being involved in the development of the world-wide notorious game "Sid Meier's Civilization IV" and having created popular innovative mods for the game. His main research interests include Human-Robot Interaction, with focus on culture related aspects, artificial emotions in humanoids, robot design, and Procedural Content Generation.

Loys De Saint Chamas graduated as a scientific baccalaureate in 1973, HEC business school in 1978, master's degree in theology in Fribourg (Switzerland) in 1987 and doctorate in theology in the same university in 1997. He has been teaching in Studium Notre-Dame de Vie (Venasque, France) from 1988 and in SILS-Waseda (Tokyo, Japan) from 2013, and occasionally in Africa (Republic of Congo and Democratic Republic of Congo). As a theologician, his main expertise are in Saint Therese of the Child Jesus, Spiritual Life, Liturgy and Religious Studies.

Masao Nishimura graduated from the School of Letters, Arts and Sciences at Waseda University and completed the graduate course at Tokyo University. He completed the Doctorial Program of Cultural Anthropology and Ethnology at the University of Michigan. He is currently a Professor on the Faculty of Letters, Arts and Science at Waseda University. Professor Nishimura conducted field research in the Philippines, Cambodia, and Laos, and has been involved in UNESCO activities including restructuring the Anthropology curriculum at the Royal University of Fine Arts in Cambodia, and restoration of The Angkor Watt temples.

Renato Paredes is a researcher concerned with computational cognitive neuroscience and human-technology studies. He has experience in the fields of experimental research methods, cognitive neuroscience and human-robot interaction. Currently, he is pursuing postgraduate studies in Cognitive Science with the School of Informatics at The University of Edinburgh. He earned his undergraduate degree in Psychology from Pontifical Catholic University of Peru (PUCP) and worked in an interdisciplinary research project named "Neurocognitive study of perception of actions and emotions in the interaction between human beings and humanoid robots" funded by the same institution.

Cesar Lucho born in Lima, Peru. He did his bachelor studies in Industrial Design at the Pontifical Catholic University of Peru (PUCP). Unlike traditional designers, he focuses on the relation of industrial design as a research tool with Human-Robot Interaction and social robotics. He worked as part of the teaching staff at PUCP and in the University of Engineering and Technology (UTEC), both in Peru. Currently, he is pursuing postgraduate studies in Design for Interaction at the Delft University of Technology, in the Netherlands.

Alexander Huerta-Mercado got Ph.D. in anthropology at New York University and the licence in Anthropology at the Pontifical Catholic University of Peru (PUCP), where he is Professor in the Department of Social Sciences. He is also columnist in 'El Comercio', important Peruvian newspaper.

Francisco Cuellar is a developer of science, technology and innovation disruptive projects with industry and academy, with experience in mining, metal-mechanics, security, telecommunications, health and education industries. Currently he is an Associate Professor of the Engineering School of Pontificia Universidad Catolica del Peru (PUCP), and Director of the Master Program on Control and Automation (PUCP). He earned BSc. in Electronics from PUCP, a MSc. in Mechatronics from Kings College University of London, a Master on Management and Politics of Innovation and Technology from PUCP, and is a PhD. candidate in Robotic Intelligent Systems at Osaka University. Co-founder of Startups: QAIRA, drones to monitor the quality of the air; and H2DRONES, marine drones for ocean and water quality monitoring and inspection.