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Nanotoxicology and Nanoethics

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Part VI

Nanoethics and Social Issues

31 Robotics, Ethics, and Nanotechnology

Jean-Gabriel Ganascia

31.1 Preliminaries

It may seem out of character to find a chapter on robotics in a book about nanotechnology, and even more so a chapter on the application of ethics to robots. Indeed, as we shall see, the questions look quite different in these two fields, i.e., in robotics and nanoscience. In short, in the case of robots, we are dealing with artificial beings endowed with higher cognitive faculties, such as language, reasoning, action, and perception, whereas in the case of nano-objects, we are talking about invisible macromolecules which act, move, and duplicate unseen to us. In one case, we find ourselves confronted by a possibly evil double of ourselves, and in the other, a creeping and intangible nebula assails us from all sides. In one case, we are faced with an alter ego which, although unknown, is clearly perceptible, while in the other, an unspeakable ooze, the notorious grey goo, whose properties are both mysterious and sinister, enters and immerses us. This leads to a shift in the ethical problem situation: the notion of responsibility can no longer be worded in the same terms because, despite its otherness, the robot can always be located somewhere, while in the case of nanotechnologies, myriad nanometric objects permeate everywhere, disseminating uncontrollably.

On the other hand, it is by no means a pointless exercise to discuss roboethics — that is, as we shall see later, the ethics of robots — in this book, because this will help, by contrast and analogy, to understand what nanoethics — i.e., the ethics of nanotechnology — actually is, or might be. But it should be stressed at the outset that ethics, whether of robots or of nanotechnology, cannot be reduced to a mere list of behavioural rules. Here, ethics differs from deontology or what some call morals, that is to say, it differs from the law. But that does not make ethics any the less a practical matter, for it bears upon our acts and our motives.

In the case which concerns us, viz., roboethics, this means that we shall be interested in what underpins the moral constraints we impose upon ourselves when designing and building robots, and the conceptual devices that were deployed to lay those foundations. We shall thus survey the different aspects of robot ethics, and in conclusion, we shall examine the relevance of these aspects in the context of nanotechnology. The chapter is organised accordingly: after a brief prehistory, then history of robot ethics, we shall discuss current affairs in roboethics. Finally, we shall examine the lessons that nanoethics might draw from roboethics, and therewith end the chapter.

31.2 Prehistory and History of Robot Ethics

Robot ethics is ancient history. It even pre-exists robots themselves, and not only their material reality, but also their name. Recall that the word ‘robot’ comes from the Czech *robota*, which means ‘hard work, chores’. It was invented by a Czech writer by the name of Karel Čapek, in a play entitled *RUR — Rossum’s Universal Robots* [1]. It refers to artificial workers ready to do whatever, and however much, is asked of them. They suffer from our indifference to them. According to Karel Čapek, these beings that we have manufactured to serve us deserve our attention from the moment they become conscious. With the help of a sensitive and intelligent young woman, the inventor’s own daughter, these humanoid robots revolt against a social order they consider unfair, and obtain human recognition.

This play, written in 1920, raised a great deal of interest, picking up on burning social issues of the day. When he came to power, Hitler was worried about it. It seems that Karel Čapek was even a favourite to win the Nobel Prize for Literature and that it was only through fear of upsetting the dictator that the Swedish Academy felt obliged to withhold this distinction from him. Very soon, there was general concern over human responsibility toward automatons.

Note that, in 1921, when Karel Čapek’s play was published, robots lived an essentially phantasmagoric existence. Of course, many automatons were built in the eighteenth and nineteenth centuries, but these mechanical replicas of ourselves remained clumsy and awkward beings. On the other hand, humans had long been trying to build artificial workers. Hence, in Book XVIII of *The Iliad* [2], we find a strange passage in which Hephaestus, the god of fire, and in particular the blacksmith’s fire, is served by robots:

On this the mighty monster hobbled off from his anvil, his thin legs plying lustily under him. He set the bellows away from the fire, and gathered his tools into a silver chest. Then he took a sponge and washed his face and hands, his shaggy chest and brawny neck; he donned his shirt, grasped his strong staff, and limped towards the door. There were golden handmaids also who worked for him, and were like real young women, with sense and reason, voice also and strength, and all the learning of the immortals; these busied themselves as the king bade them.

Closer to our own time, the Jewish cabalistic tradition reports the existence, toward the end of the sixteenth century, of a clay statue called the Golem, which was made by Rabbi Loew, better known as the Maharal of Prague [3]. Like contemporary computers, this machine came to life when a message was passed behind its teeth. Usually, it busied itself with everyday household tasks, like an eager and diligent servant.

This extraordinary statue inspired many legends. According to one of these, one Saturday, day of prayer, Rabbi Loew had forgotten to remove the

message from behind the Golem's teeth, whereupon it began to get agitated, shouting and terrifying all the neighbours, while the master was fulfilling his holy duties down at the synagogue. When he got back, Rabbi Loew destroyed his creation for fear that it might resume its troublesome initiatives. According to another story, the word EMETH appeared on the Golem's forehead. In Hebrew, this means 'truth'. Now it is said that, one day, the Golem picked up a knife in order to remove the first letter of this word. This would have left 'METH', which means death in Hebrew.

All these mythologies leave an aura of ambivalence about the Golem which foretells the ambivalence of contemporary technical achievement. On the one hand, Rabbi Loew, who had the knowhow to create such a perfect object, was widely praised, even worshipped, to the extent that the chair on which he used to sit is still on display in the old synagogue in Prague. On the other hand, such a thing as the Golem sometimes runs the risk of escaping its masters and creators, who must of course prevent such a thing from ever happening. Our general responsibility with regard to human technical creations, and in particular machines, is so clearly stated here that Norbert Wiener refers explicitly to it in *God and Golem* [4], a work entirely devoted to the ethical issues of cybernetics and the first computers.

To cut a long story short, the threat that robots raise for humanity has always been present. In 1938, tired of reading so many poorly conceived stories of invasive and aggressive robots, the Russian-born biologist Isaac Asimov put together a series of short stories and novels [5], organised around three immutable laws of robotics, to which he adjoined the necessary add-ons as required for the development of his undertaking. These laws underlying the creation of androids are intended to prevent them from ever harming human beings:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

To sum up, this hasty foray into the prehistory and the history of robotics has shown us the long existence of the robot, or more exactly, its long existence in the human mind, which goes back at least as far as Ancient Greece. And jointly with the phantasmic presence of Pygmalion, Pinocchio, and all kinds of animated statue, ethical preoccupations were also born from the earliest times: how can we ensure that whatever controls its own animation and moves by its own means does not become autonomous? What limits should we impose to ensure that our creations do not swallow us up? Sometimes one must have the courage to destroy what one has made. This is the lesson we learn from the legend of the Golem.

In every case, the robot acquires an analogous status to our own. It looks like our double, but we are to the robot in the same situation as God — or Nature in an atheist perspective — is to us. Indeed, robots are our creatures just as we are the creatures of God or Nature. This makes the whole affair all the more daring and risky. It also explains why we think of imposing on these artificial beings the same restrictions as we impose upon ourselves before God. Note finally that, symmetrically with this requirement of the robot's deference before humans, we sometimes speak of human responsibility with respect to robots, analogous to that of God with respect to humans. On this point, the enigma of *RUR* — *Rossum's Universal Robots* [1], the play by Karel Čapek, is eloquent. And other works of science fiction also adopt this line of thinking. We might also wonder whether these perspectives are relevant to nanotechnology. However, that is not our subject. Here we are hardly concerned with imaginary representations of robots, but must focus rather on the contemporary reality of robotics and on the many questions it raises.

31.3 Roboethics

By roboethics we understand here anything that touches upon the ethics of robots or the ethics of humans with respect to robots. The term was invented in 2002 by Veruggio, and officialised by the first roboethics symposium, held in San Remo in January 2004 [6]. It was deliberately coined to resemble the word 'bioethics' and now seems to be used by scientists in official publications, by universities, by professional associations, and so on. The field of application of roboethics has grown considerably with the increase in the number of robots and with the ever greater role they play in contemporary economics. In this respect, it is worth noting that the active robot population in manufacturing industries is now something like a million 'individuals', and to this one must add housekeeping robots, companion robots, space robots, medical robots, drones, robot soldiers, etc., not to mention an uncountable number of virtual robots zipping back and forth on the Web. In short, we are living today in a new world where humans coinhabit more and more often with robots. This raises many questions. How should we assume this new human condition, living in symbiosis with robots? Is there no risk of becoming, if not the victims, at least the slaves of the machines which we originally designed to serve us?

31.3.1 A Roadmap for Roboethics

These are perfectly legitimate questions. They have been tackled in several different ways. We shall not give an exhaustive description of all the deliberations that have been brought to bear. Instead, we shall simply discuss a report drawn up by the European Robotics Research Network [6] to deal

with ethical questions. This report resulted from a workshop held from 27 February to 3 March 2006. Its very existence attests to the need felt by scientists to tackle these ethical issues. The same can be said in the context of military robotics in the US, where analogous reflections have been conducted.

Having mentioned Asimov's laws and recalled what is meant by ethics, the report shows that, even if robots can be reduced to assemblages of deterministic mechanisms, that does not imply that they have no ethical dimensions. More precisely, insofar as they are able to act autonomously, they are agents. Of course, they do not have autonomy of the will, in the ethical sense, and do not possess consciousness. In this respect, they are merely machines. But they appear so complicated that we would not be able, during the time of action, to anticipate all their determinations. From this point of view, we must treat them as being endowed with autonomy. The understanding that we have of them no longer passes solely by the relevant physics, even though they are constructed using material constituents all of whose properties we are able to control perfectly. There is a sphere of intelligibility of robots which helps us to apprehend them by thinking of them as intentional systems, in other words, as agents with goals, desires, emotions, etc. It is by reference to this sphere that we can perceive of them as moral agents. More precisely, since robots are viewed as agents, we attribute their actions to them. But the consequences of their actions can greatly influence the lives of human beings in society. They sometimes improve our lives, but there is a risk that they may be detrimental to them. We thus make the distinction between those that act for the good, i.e., for human happiness, and those that cause harm. And here we may attribute morality to them. It is in this sense that robots are qualified as moral agents.

To establish the moral value of robots, the report reviews all contemporary applications of robotics. It constructs a taxonomy and for each category it indicates the risks, before making recommendations. This classification of contemporary robots arranges them in six families which are themselves divided up into kinds and species. Here is a synopsis of the classification:

- **Humanoids.** These are characterised by their resemblance to humans. They are subdivided into artificial minds and artificial bodies.
- **Production Systems.** These mainly concern industrial manufacturing and remotely controlled work in hostile environments, such as the reactors in nuclear power stations and flexible workshops. They include many kinds of robot, depending on the application and depending on whether the robots are autonomous or remotely controlled, but these technical distinctions are irrelevant from our present point of view, which concerns the ethics of robots.
- **Adaptive Domestic Robots and Intelligent Houses.** This class of robots covers indoor robots and ubiquitous robots, also called onboard or mobile robotics.

- **Outdoor Robotics.** This covers land robots, marine robots, airborne robots, and space robots.
- **Medical Robotics.** This includes surgical robotics, biorobotics, intelligent medical assistants, including aid and diagnostic systems and monitoring systems, and robotics for biocomputing, e.g., protein and genome sequencing robots.
- **Military Robotics and Intelligent Weapons.** This includes autonomous vehicles, on land, in the sea, or in the air, intelligent bombs, automatic surveillance, etc., robot soldiers and systems for improving the motor and/or perceptive performance of humans, especially exoskeletons which considerably increase human stamina capabilities.

For each of these categories of material robots, lists were drawn up to produce an inventory of the perils awaiting us and the elementary precautions required to save us from them. For example, it is easy to imagine a domestic robot taking unfortunate initiatives or doing silly things, such as burning a shirt it is ironing or swallowing the wire from an electric lamp when doing the vacuuming. We are all afraid of seeing a machine which, at the patient's bedside, decides without proper medical consultation to greatly increase the dose of a given medicine. Our knees shake at the thought of a robot soldier arriving to carry out its 'mission', while systematically eliminating all those that might get in its way.

But these are precisely the kind of quite ordinary situations we will soon have to face up to. Laboratory studies and military projects in Europe and the USA should soon convince us of this. In this respect, the above-mentioned report [6] is eloquent, being written by robotics researchers who are fully aware of the state of the art, the work that is currently underway, and the projects in the pipeline. Worse still, it happens that, in quite unexpected situations, robots make wholly disconcerting, even shocking decisions. When the risks are known, we should be able to protect ourselves from their consequences. But how can we guard against a hazard that we do not know? And if a robot were guilty of reprehensible acts, who should be treated as responsible? Should we incriminate the robot's designer, its maker, or its owner?

Some say that the situation is changing now that machines are becoming more and more autonomous. For these commentators, the law must change too, to define the status of complex material systems whose behaviour may now escape both their designer's and their owner's control. Others think that legal fictions have long existed, and that with suitable adaptation they will allow us to handle these contemporary realities. In the opinion of these commentators, we could for example attribute to intelligent robots an analogous status to that of slaves in Ancient Rome. Indeed, the slave could be punished, but his acts engaged his owner financially, the latter being held legally responsible.

Whatever is done, a new approach must be put together, involving clear principles, laws, and a jurisprudence. It would not be possible to envisage all

the applications of robotics, and hence all the risks we run. So the intention is to establish new rules as soon as the new threats are identified. This is the subject of the roboethics roadmap put forward by the above-mentioned roboethics working group: to set up protocols for establishing these rules.

31.3.2 Ethics of Virtual Robots

Apart from material robotics whose inventory we have just outlined, there is also a field of virtual robotics. As the term implies, it is not deployed in the external world, but solely in universes which, like *Second Life* [7], are qualified as virtual because they consist merely of digital data flows.

As an illustration, US researchers have designed intelligent agents which they call elves, because they follow you around everywhere from dawn to dusk, like benevolent spirits. The elves read your emails, manage your timetable, and record your phone calls. They send you well-meaning SMSs to draw your attention to various issues. They assist their masters as best they can. For example, they make appointments like diligent secretaries, they book plane tickets, they do the shopping at the supermarket, they deal with administrative matters, they reserve seats at the theatre for family outings in the evening, and so on and so forth.

However, from time to time, these agents make mistakes despite themselves and create problems for their charges. There are tales of these wonderful elves carrying out quite reprehensible tricks on their owners by simple inadvertence [8]. For example, a university bod had a paper to finish by the end of the day, but the list of people who wanted to meet him kept growing longer and longer in his diary that particular day, out of all proportion, simply because he was unable to explain to his agent that, although he was in his office, he wished on no account to be disturbed. Another was woken at 3 a.m. by his elf, who wished to inform him that the plane he would take that same day at 11 a.m. would be delayed by one hour. Well, these are minor discomforts and there is nothing there to offend our ethics. But that may not always be the case.

Let us return to the example of the elves. They offer their charge the possibility of setting up an order of priority among their appointments, in such a way that it is always possible to postpone some of them. For example, if you get a phone call from the director who needs to see you urgently, whereas you had planned to meet your secretary, the elf takes it upon itself to postpone the latter engagement. In this perspective, how would you explain to one of your students that she does not have absolute priority when she is just in the process of finishing her doctoral thesis? Perhaps one should not allow elves to reveal their orders of priority? But if this is the case, it means that we must make disassembling robots. Is that ethical? More generally, elves know a considerable amount about us. Should they communicate it when asked? If not, how do we justify their holding it back?

In addition to these general questions regarding the discretion of virtual robots [9–11], there are ethical problems with the Internet itself. Should we authorise robots to systematically exploit all the data they come across, disclose it to as many people as possible, and disseminate it unreservedly on the Web? This raises questions relating to the protection of privacy. But it also bears upon what is allowed or not allowed on the Web.

To deal with the first point, let us stress that more and more data about private individuals are stored on the Web. Today all sorts of data relating to our movements, our health, our purchases, and our taxes are going through the Web. Anybody succeeding in bringing them together would have a considerable power over us. In this respect, recall that during the election campaign for the United States presidency, Barak Obama built up a data base which collected information about most American voters. By examining this data base in detail, he targeted those who were likely to swing, and for each such voter, he chose the militants best placed to convince them. Should it be forbidden to create this kind of data base? Does the protection of privacy necessarily mean storing personal data in unbreakable safes? Today many people consider that we are the owners of all information about ourselves, in other words that we have an inalienable moral right over photos, images, or recordings that refer to us. As a consequence, we should be able to control the dissemination of information relating to our person and preside over what others have the right to know about us, giving or withholding our explicit consent to any request that concerns us specifically. However, such theoretical principles come up against the problems of everyday usage and obvious material stumbling blocks.

The second important point concerning virtual robotics relates to the proliferation of robots on the Web. We have all been the victims of computer viruses, Trojan horses, or other electronic threats. This evil-doing bestiary of injurious robots must of course be wiped out. It is no longer the doing of talented or facetious youngsters. Computer delinquency is now rife. Today, organised groups control this virtual zoo of worms, viruses, and other deleterious software. These groups blackmail the major industrial companies. If they do not pay the ransom, they suffer massive attacks that temporarily disable their computer system. This kind of racketeering or warlike behaviour must of course be condemned.

Another example are the search engines which continually aspire to assimilate absolutely the whole content of everything available on the Web using virtual robots, and then index these contents. Naturally, no one is at issue with search engines, which have become quite indispensable today. However, we need to avoid such robots deploying in such a massive way that they actually saturate the Web. Moreover, insofar as possible, we would like to protect certain private data on the Web. To this end, there is an ethical code for robots which has been perfectly formalised [12] and which has indeed been implemented throughout the Internet. A file called `robot.txt` is associated

with each Website that contains confidential information. This is where you may explicitly declare that you wish to exclude your site, or part of your site, from the field of action of robots. Associated with these files is an exchange protocol which robots exploring the Web are supposed to respect. If they do not, they risk being qualified as harmful, then pursued, or even excluded from the system.

31.3.3 Responsibility Toward Robots

To conclude this section on roboethics, let us also mention an important dimension from a symbolic point of view, although it does not bear upon the ethics of robots, i.e., on the rules that humans must respect when they build or use robots, but rather upon the ethics of humans with respect to robots considered as autonomous beings. Should we be allowed to treat robots just as we like, on the pretext that we made them and that they are our creatures? The play *RUR — Rossum's Universal Robots* [1] written by Karel Čapek illustrates this point very clearly. And likewise the film *AI — Artificial Intelligence* made by Steven Spielberg in 2001 in homage to Stanley Kubrick. The question may seem absurd in view of the feeble performance of today's robots. But it is a matter of principle: if we manage to build automatons able to make decisions, possessing an artificial conscience, and able to suffer, would we then not have obligations toward them?

A second, more acute and more pressing question concerns virtual robotics and the respect we owe to our intelligent agents. The contemporary philosopher Luciano Floridi claims the existence of a new stratum of intelligibility, the infosphere [13, 14], which is defined by analogy with the biosphere, the environment of living beings, as the environment of all informational entities. These include search engines exploring the Web, automatons populating virtual worlds, and avatars through which we may interact in video games or with digital universes.

According to Luciano Floridi, since the theory of information governs the infosphere, the fundamental ethical criterion of the infosphere should be based on the concepts arising from this theory. The philosopher thus founded what he calls information ethics, basing it on the notion of information entropy introduced by the mathematician Claude Shannon (1916–2001) [15] at the end of the 1940s as the basic feature of his theory of information. Just as entropy in the physical sense measures the disorder of a system, in other words the absence of knowledge we have about it, the entropy of information measures the disorder of an information system. And in this context, the interest of a message is measured by the extent to which it tends to reduce the information entropy of the whole.

In physics, the entropy of a closed system always increases in time, which means that such a system always tends to become more disorganised. It is this unavoidable increase in entropy on our planet that leads some to say, incorrectly, that we lack energy, while the total energy remains the same.

What we refer to as energy consumption should strictly speaking be called entropy increase. And it is this growing entropy that is detrimental. Likewise for the infosphere, that is, the environment of the informational entities within which we are now condemned to live. For this, too, undergoes an increase in entropy, which means that we have less and less control over the information that diffuses through it. Once again, it is not that there is a lack of information, far from it. The problem is the degradation of its quality.

An ethical attitude in the infosphere is therefore measured, according to Luciano Floridi, by the reduction it can bring to the information entropy. In the name of this ethics, we thus reprove the spreading of false rumours and the scrambling of news by tidal waves of meaningless messages. Likewise, any destruction of an informational entity that would lead to a permanent loss of information would be clearly condemned. In short, information ethics as formulated by Luciano Floridi would have us respect all informational entities as such, whether they be simple avatars of our fellow humans, representatives of their interests in the infosphere, or artificial agents carrying information.

31.4 Extrapolation to Nanoscience

In order to extend the discussion from the subject of this chapter, which is roboethics, to the field of nanoscience, we shall not by describing or alerting against the risks involved in nanoscience, and nor shall we try to put forward solutions there. We shall simply tackle the question reflexively, by examining what guided robotics specialists in their ethical investigations and seeing how this might lead to a similar investigation in the field of nanoscience. For this purpose, we shall tackle three crucial issues. One bears upon the reality of the risks, the second discusses the possibility of a nanoethics roadmap comparable to its counterpart for roboethics, and the third investigates the possible distinguishing features of nanoethics.

31.4.1 Reality and Virtuality

As we have seen, much of the discussion about roboethics, as stimulated for example by Rabbi Loew at the end of the Middle Ages [3], or more recently by Isaac Asimov [5] and Karel Čapek [1] at the beginning of the twentieth century, took place before robots even achieved any real existence. These imaginary constructions underpin our current feelings about robotics. They are the starting point for our reflections on the ethics of robots. For example, the protocols laid down today for virtual robots [12] are inspired by the laws of roboethics invented by Asimov [5]. The world of imagination thus plays an important role in our consideration of ethical questions relating to the development of science and technology.

As a consequence, we should pay careful attention to the projections we make on nanoscience. These announce risks due to anarchic proliferation of

self-reproducing nanoscale objects. There is no doubt that such risks should be examined with due care. Indeed, the comparison serves as an intellectual stimulus and in this respect is therefore a good thing. However, such announcements also require a circumspect and critical attitude, because if we are not careful, there is a risk of paralysing any further developments for no valid reason. Recall, for example, the scaremongering predictions of Bill Joy, founder of Sun Microsystems, in 2000 [16], or the fiery declarations of so-called demiurges, like Hugo de Garis who got his name into the main Paris newspapers by announcing the inevitable creation of artificial beings far superior to humans [17], or the prophecies of Hans Moravec [18] who claimed soon to be able to couple the human brain to computers to transform us all into cyborgs, that is, cybernetic organisms.

Faced with this kind of proclamation, is there not a danger of concealing the reality behind unfounded fears, or being blinded by such? In other words, referring back to Floridi's principles of information ethics [13, 14] as discussed above, are we not confronted here by willful and quite undesirable amplification of information entropy? When we consider such ill-considered claims, it seems urgent to make a meticulous and complete inventory of the risks, like the one produced by European robotics specialists. In this area as in any other, an ethical attitude consists in discussing and elucidating the issues, rather than stirring up unfounded fears.

31.4.2 Do We Need a Roadmap for Nanoethics?

However, even if we manage to build a complete inventory of the risks involved in the development of nanoscience, that does not mean that we shall be able to predict the unpredictable. What actually happens sometimes escapes prediction. We need to prepare for that and attempt to react. The role of ethics is not to end all discussion by imposing some incontrovertible rule. Quite the opposite. Ethics should open our minds to what may come upon us.

The idea of a roadmap is precisely to satisfy this requirement. It is not a catalogue, nor a digest, nor a compendium, nor a treaty. It does not purport to assemble all knowledge, all laws, or all rules. It sets out waymarkers, it provides indications, it suggests principles which, at the opportune moment, will help us to cope with a situation. It should be useful to industry and public authority alike. It will allow us to send out warning signals and make decisions.

To illustrate its role, here is an anecdote. A few years ago, I was invited to assess projects for the European Commission. At the time, I was certainly less aware than I am today about the ethical questions relating to the development of new technologies. But I was nevertheless extremely disturbed by a project for an 'intelligent house' where, for the safety of its occupants, every movement of every individual was continuously recorded and analysed by computers. We were asked to tick a box if we felt that any ethical problems

might be raised by the development of such a project. But when I exposed my concern, explaining that I wished to tick the box and ask the project's architects for further explanations, I found myself sharply scolded by the EC representative. In his opinion, much worse things already existed in the United Kingdom, where pedestrians were being filmed whenever they stepped into the street. So there was no question of letting trifles stand in the way of strategic European industrial developments. At the time, I gave in, but today I regret that decision. I now believe that the existence of a roadmap, agreed by representatives of the scientific community who had carefully considered the ethical consequences of the applications of their work, would have been of great assistance.

31.4.3 Collision and Contamination Between Spheres of Intelligibility

The roboethics roadmap is certainly useful, and the same may well be true for nanoethics. On the other hand, the roadmap may not be sufficient for roboethics. Indeed, it has proved necessary to introduce new concepts in order to tackle the issues raised by virtual robotics. This is what justified the introduction of the notions of infosphere and information ethics by Luciano Floridi. Will the same be true for nanoethics? It is with this open question that we would like to continue the parallel between roboethics and nanoethics.

To get a good grasp of Floridi's ideas, I believe it important to read him from a Spinozan perspective, which happens to be his own. From this standpoint, information corresponds to what Spinoza calls, in *The Ethics* [19], a mode, that is, a particular way of being of substance, or in more contemporary terms, a sphere of intelligibility of reality. So just as for a human beings the extension mode is the body and the mode of thought is the mind, so the mode of information is the informational entity. In short, a given thing can be simultaneously viewed as being in different modes. As we have just seen, virtual robotics can be viewed both in the extension mode, as belonging to the sphere of intelligibility of physical phenomena, and in the informational mode, as belonging to its own sphere of intelligibility, which can be apprehended via concepts from the theory of information.

Let us now reconsider nanoethics, and try to transpose the conclusions we have just drawn. Then we may ask ourselves what sphere of intelligibility nanoscience and its progeny belong to. Clearly, they take on a meaning when viewed as physical (or chemical) matter, when viewed from the standpoint of the environment of living beings, i.e., with reference to the biosphere, and when viewed from the standpoint of information, i.e., with reference to the infosphere. Among these different points of view, is there one more fertile than the others for laying down the principles of nanoethics, or is there a sphere of intelligibility intrinsic to nanoethics? Or should we appeal to several spheres at once? And if so, is there not a risk of these spheres of intelligibility colliding and contaminating one another, and thereby generating confusion?

In concrete terms, that would mean that, in the field of nanoscience, any attempt to consider a phenomenon as belonging to a single order of intelligibility, for example, that of physics, biology, or information science, would be perfectly ineffectual, because the objects, by their essence, would systematically elude it. Does the claimed convergence between nanoscience, biology, computing, and cognitive science not betray the disquiet that is felt, rightly or wrongly, before the imminence of this contamination between spheres of intelligibility? If the risks of contagion should be realised, this would mean that nanoethics is in fact unique and in this respect could not benefit from experience acquired in roboethics. If not, for each of the hazards due to development of nanoscience, it suffices to identify the sphere it belongs to. In any case, before talking about nanoethics, the first thing is to clarify which sphere or spheres of intelligibility the nanosciences belong to and then establish the boundaries of each such sphere.

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