Modeling in Ethics Engineering

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ABSTRACT: *Modeling of systems, for example, communication systems, involves identification of their basic components and interrelationships. This paper proposes a model of ethical systems based on the notion of flow. The flow of ethical rules, for example, ought not lie, is conceptualized to trigger the flow/blockage of other flows such as information flow. In this scheme different types of mechanisms can be identified for classifying systems. Lying is used as an example of an ethical issue to illustrate the proposed approach.*

Keywords: Ethical system, System models, Communication systems

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1. Introduction

Artificial life involves behavior in manmade systems typically considered characteristic of living systems. Characteristics of this behavior include intelligence and self-awareness, and their ethical implications. Artificial life processes cannot be meaningfully understood without a value-based (intrinsic) perspective. The moral dimension is in particular an essential ingredient. To a great degree, this ingredient involves humankind, its communities, and its artifacts. In this paper we conceptually model ethical concerns that may have significant ethical implications for modeling of human ethical systems, as well as those of artificial moral agents. A model is a conceptual abstraction that describes features of interest of artificial and biological systems. Conceptual modeling provides an exploratory foundation for understanding these systems and explaining the phenomena under consideration. The model can be used as a common representation to focus communication and dialogue.

Ethical systems are typically described as "principles for distinguishing right from wrong" and "cultural beliefs about proper behavior." They are complex, with overly verbose descriptions of mental models and deeply ingrained philosophical assumptions. It seems that the process of development of conceptual abstractions of these systems has not been explored. In our approach there is a strong association between systems and their models. A system is "defined" through a model, for example, depicting communication systems in terms of a model of sender, channel, and destination. We also conceptualize a system in terms of "states." The state is a fundamental concept that presents information about the system's mechanism, represented by transitions and relationships among states. Accordingly, we view an ethical system as a system of "things of ethics" (called ethicthings). The system is specified by the states of these ethicthings and their transitions. Furthermore, we conceptualize an ethical system in terms of two subsystems: an ethicthings subsystem, and an applications subsystem. In the context of lying, the application subsystem involves flow of information/ misinformation. Our goal is to propose a model of ethical systems closer to "formality" and detached from epistemological issues. Since lying is used as a sample ethical issue for the proposed approach, we first review the basic notion of information and lying (sections 2 and 3). In section 4, the flow model that forms the foundation for constructing flows of ethical rules and information is briefly described. A general view of the materials in this paper is shown in figure 1.

2. Information

Information is typically defined as data plus meaning. We use the term "information" here in its ordinary sense of factual report. Information is materialized in terms of informing statements that include synthetic statements that can be empirically true/false or conditional [21]. Misinformation is defined as a false assertion; however, we will use the term "information" to refer to both information and misinformation. One justification for doing so is that we are not concerned with aspects that associate information with reality. In our system, truth and falsehood are assigned by moral agents. Moral agents refer to humans, organizations, and artificial agents. Moral agents form the class of all entities that can, in principle, qualify as sources of moral action [10].

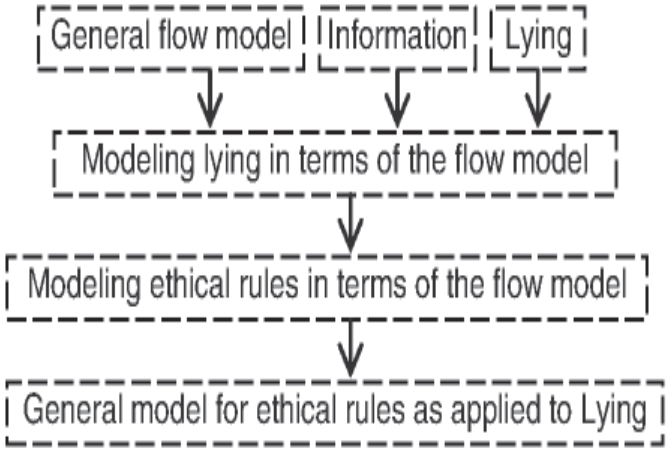

Figure 1. General view of the materials proposed

3. Lying

We apply our methodology of representing ethical systems to lying. Lying is described as "the most significantly destructive political act in the Information Age" [23]. A "lie" is often used as a synonym for falsehood, or untruth. It means misinforming with the intent and the will to mislead another person; however, not every falsehood is a lie. A person who gives false information without intending to deceive is not considered to be lying; similarly, false information given as the result of bad judgment or mental illness is not a lie.

So-called formal lying refers to making statements that a person believes not to be true. Thus, to lie is to make assertions that are untrue, regardless of the actual situation (discourse) in terms of truth or falsity. We will limit ourselves to this falsification or "formal lying." Accordingly, we concentrate on the act of "intentionally asserting what is false" or "intentionally falsifying what is true," and not on the act of "intentionally deceiving someone" (Aquinas; see [16], 315). Generally a false statement need not be a lie if the speaker believes that it is information, and a true statement need not be not a lie if the speaker believes it is misinformation. Ethical traditions and philosophers generally oppose lying. According to Immanuel Kant, lying is morally wrong because it corrupts the human being and harms other humans. Virtue ethics preaches "unity of the virtues"; hence, lying is morally wrong because it turns away from such an ambition. Utilitarian ethics claims that lying is morally acceptable only when the consequences maximize benefit or minimize harm.

We will describe lying in terms of the flow of information/misinformation in a five stages schema representing the *states* of information/ misinformation inside the moral agent. Inverters in the stream of flow may change the true/false values before releasing the information. In preparation for such a specification of lying, the next section reviews a model of information flow.

4. Flowthing model

The "flows" within a system are important factors in the intertwining of its connected components. We concentrate on a specific type of system: a system of "things that flow" or *flowthings*. "Things that flow" include information, materials (e.g., in manufacturing), money, and actions. The concept of flow is widely used in many fields of study. In economics, the goods circular flow model is well known; in management science, there is the supply chain flow. In computer science, the classical model of flow is the 1949 Shannon-Weaver communication model, representing electrical signal transfer from sender to

receiver. Flow of information means movement from one information sphere (the sender) to another information sphere.

Recently, a *flowthing* model (FM) has been proposed and used in several applications, including communication and engineering requirement analysis [2, 3, 5]. In FM, the flow of *flowthings* indicates movement inside and between spheres.

The sphere is the environment of the flow and includes five stages that may be subspheres with their own five-stage schema. The stages may be named differently; for example, in an information sphere, a stage may be called communication, while in raw material flow, the same stage is called transportation. The information creation stage may be called manufacturing in materials flow.

We will assume that the "thing that flows" is information. An information sphere denotes the information environment. The lifecycle of information comprises a sequence of states as it moves among stages of its lifecycle, as follows:

1. Information is received (analogous to passengers arriving at an airport)

2. Information is processed (i.e., subjected to some type of process such as being compressed, translated, anonymized, etc.).

3. Information is released (i.e., it is designated released information, ready to move outside the current sphere, such as passengers ready to depart from an airport).

4. Information is transferred/communicated to another sphere.

5. Information is created (i.e., generated as a new piece of information).

These five states of information (received, processed, released, transferred, and created) form the main stages of the stream of flow, as illustrated in figure 2. Each stage may include substages, such as storage and usage. Information may also be "destroyed" in any stage.

Storage is not a basic state of information. Received information is stored, processed information is stored, created information is stored, and transferred information is stored. The "storage" in each of the five stages represents information in a static state. As information is received, it may be stored in its received condition for a later time when activated by being returned to the flow stream.

On the other hand, information cannot be simultaneously in two of the basic five states mentioned previously. At the moment of being processed, received information is no longer in the received state. When processed information is released, then it is no longer in the processed state. Created information is *new* information generated in the system; hence it cannot be in the processed, released, received, or transferred states.

Flows trigger other flows. Imagine that a person in Barcelona (sender) uses the Internet to ask a person (recipient) in New York whether it is raining in New York. First, the query flows to the receiving stage of the New Yorker. It triggers the New Yorker to some type of *action* (e.g., opening the window to check whether it is raining). Triggering indicates a change in the "thing that flows" from information to action. Actions can also be received, processed, created, released, and transferred. The action of the New Yorker triggers the creation of a response (information) that flows back to Barcelona.

FM is a model of things that flow. To use a neutral term, the term *flowthing* denotes a thing that flows, hence, is received, processed, created, released, and transferred. In FM, a system denotes a dynamic movement (flow) of *flowthings* inside and outside the system. The system structure is defined in terms of the five stages schema, as described previously.The FM shows the minimum necessary states that exist for describing transformations of information. It is simple and limited to five stages suitable for decomposing and analyzing.

5. A model of lying

Applying FM to the process of lying, we conjecture that assigning truth/false values to a piece of information is a type of information processing. In FM, there are two types of information:

- New information that comes from two sources: the created stage or received from outside.

- Current-flow information that may change form, location, multiplicity (through copying), activity (stored/ flowing), etc.

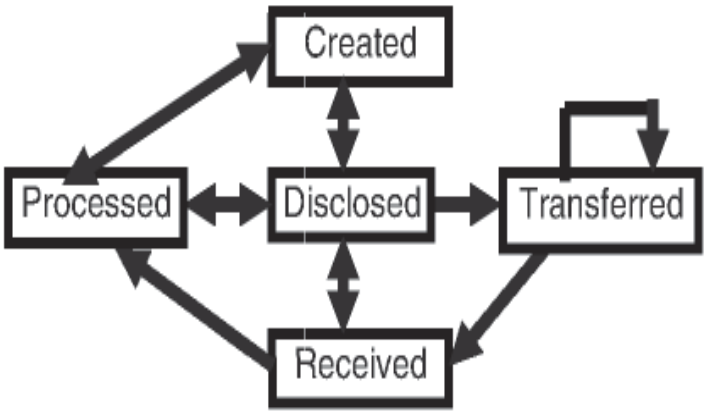

Figure 2. Information states

Processing in FM refers to some type of treatment of information that may change the form of information, including assigning truth/falsehood values. Synthetic statements are, by definition, applicable to true/false assignment. The FM does not distinguish between information and disinformation, as in logic, where both x and (not x) are formulas, or in the communication system of sender-channel-destination, where 0 and 1 are exchangeable. As we will see later, an FM-based model of ethics does not decide whether the ethical statement is bad or good. Truth/falsehood and good/bad are only tools that provide categorization and existence, as one or the other does not disturb the system. The justification for such a position is that our goal is to base our proposed model on "formality" and to detach it from epistemological issues.

Nevertheless, we distinguish between assigning true/false values to received information and to created information, as follows.

5.1. Received information

When information is received, it flows to the processing stage to be assigned (the agent's) true/false value. For example, upon hearing that It is raining outside, the agent assigns it a true value because It is raining outside is processed and determined to be coming from a reliable source. Or, upon receiving this information, the agent goes to the window, looks outside, and, if it is not raining, assigns a false value to It is raining outside. In both cases, assigning a true/false value to received information is performed at the processing stage.

Releasing received information without processing makes the agent neutral with respect to the lying issue.

5.2. Created information

Similarly, assigning true/false value to created information is performed at the processing stage. Suppose the agent is in the street when it is raining. The agent creates It is raining outside and assigns to it the truth value, based on his/her/its experience in the street. That received sensual information from the condition in the street is the basis for assigning truth value to It is raining outside.

In addition, releasing created information without processing it (e.g., spontaneous outburst) makes the agent neutral with respect to the lying issue; i.e., he/she/it is neither a truth nor a falsehood agent.

5.3. Lying as an inverting process

Lying can be conceptualized as a process that inverts the assignment of true/false values of information, as shown in figure 3. The figure is a copy of the FM model shown in figure 2, and includes the following processes:

- Assigning true/false value: This process takes pieces of information (received or created), and assigns to them (the agent's own) true/false values. Of course, these values are assigned according to the agent's persuasion that is built upon his/her/its "state of knowledge." We do not specify here the method of assigning these values.
- Two "selection processes" that select (thus, separate) information with true value and information with false value.
- Two "inverting processes" that invert true/false values. The arrows between "Assigning true/false values" and "Inverting true/false values" denote the flow of information from one process to another in the processing stage.

Thus, we have four possible types of flows of information, as described in Table 1. For the examples in the table, we assume

that the agent assigned true to It is raining and false to It is cold. Such a model of flow of information that includes assigning and inverting of true/false values can be used to define a lie. It is information that flows through the path:

	Type of information	Examples
1	Inverted true-value information	Releasing It is not raining
2	Information with true-value	Releasing It is raining.
3	Information with falsevalue	Releasing It is cold.
4	Inverted false-value information	Releasing It is notcold.

Table 1. Possible flows

… '! Assigning true/false values '! Inverting true/false values '! Releasing '! Communication In addition, Truthfulness is releasing information from the paths

…'! {Selecting true information, Selecting false information} '! Releasing '! Communication Falseness is releasing information from the paths …'! {Inverting true information, Inverting false information} '! Releasing '! Communication Accordingly, this model involves an intermediary process of inverting true/false values, as shown in figure 4.

In this case, belief is the process of assigning true/false values. For example, the agent may receive It is raining as true; however, he/she/it may assign false to It is raining.

The type of analysis shown in figure 4 is not new; however, specifying it in terms of processes in the context of the information flow model is new. The model provides definitions suitable for artificial agents. It also locates these definitions within the whole structure of the information handling system. Next, we supplement this model with a model of ethical rules.

This last model will act as a "watchdog" over the paths of information flow. In addition, the FM provides the basic structure and flow of ethical rules.

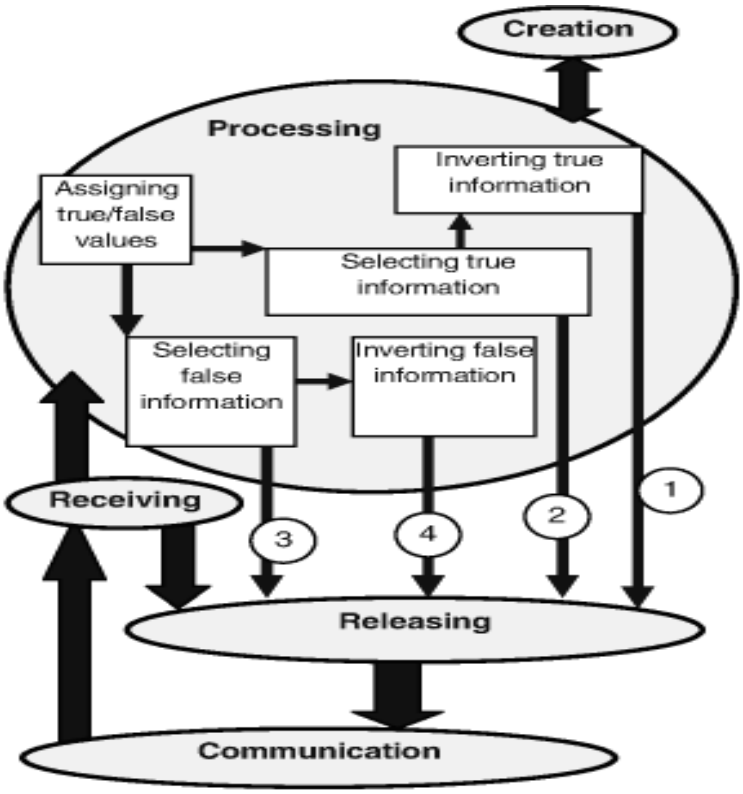

Figure 3. FM process that assigns truth/falsehood value to information

6. A model of ethicthings

In this section, we assume that ethical statements (which may be called values or ethical rules, e.g., ought to) are a type of flowthings. They certainly have the properties of flowthings. They are created, received, processed, released, and transferred.

The phenomenon of receiving (instilling) values and ethical rules is very familiar. Social institutions are built on transferring these values and rules from one generation to another. Similarly, these values and rules are continuously created (e.g., prophets, social leaders) and exchanged (received, communicated), analyzed (processed, translated), and released in different ways. Their system of circulation can be modeled by the flow model. They are also stored, copied, or destroyed, as in the case of any flowthing. For an individual moral agent, ethical rules are flowthings (may be referred to as ethicthings) in his/her/its FM. In addition to a flow of information, actions, etc., we can postulate that the agent has a flow system of ethicthings.

This system of ethicthings, as in the case of other flow systems, may "influence" the flows in other systems. We are concerned here with the structure of this ethicthings system and its relationship to the agent's other systems such as information and actions. From the ethical point of view, goodness and badness are central notions of any ethical system. We will not deal with the standards for judging actions, the criteria of judgment, or the intentions of the agent actually performing the action.

Without loss of generality, we consider ethicthings to be ethical statements in their prescriptive form, that is, they can be reworded to ought statements. These ethical statements prescribe what is right, wrong, good, and bad about human character, behavior, and relationships [21].

Accordingly, ethical statements that embed "ought" can be modeled in a flow system, as shown in figure 5. The figure also shows the processes of selection and filtering of these statements. Ethical rules can be received or created, then processed, as in the case of information.

The inverting in figure 5 denotes negating (ought $\rightarrow$ ought not or ought not $\rightarrow$ ought) an ethicthing upon releasing. Releasing an ethicthing means a decision to discharge it to be realized as an action.

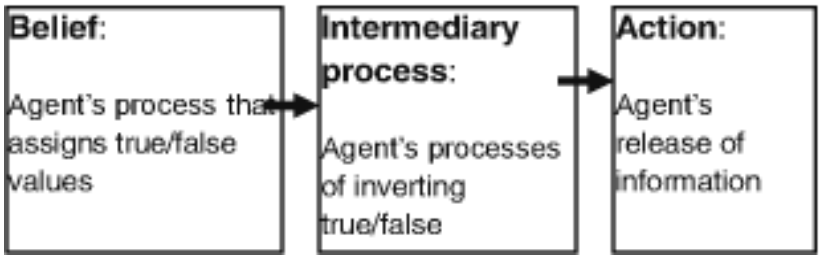

Figure 4. Information lying is modeled as caused by intermediary processes between the belief and the actual action of releasing information

For example, suppose that the agent has the ethical rule Ought not to lie. This means that Ought not to lie is being adopted as one of the selected rules to be followed (one of the believed ethical rules); however, for some reason such as fear of reprisal, and in an actual situation, the released rule is Ought to lie. In this case the agent is not acting according to his/her/its ethical belief.

Here we distinguish between informational belief and ethical belief. Ethical belief is the process of assigning ought/ought-not values to ethical rules. Similarly, we distinguish between information lying and ethical lying. Information lying is inverting the true/false values of information, and ethical lying is inverting the ought/ought-not assignment to ethical rules.

7. Robots that lie

The task remains to connect information flow to ethicthing flow. In this section, we concentrate on artificial agents such asrobots. In one experiment, it was reported that robots were created [9] and placed in habitats containing both glowing that

"food patches" that recharged their batteries and patches of "poison" that drained them. They were given software genes determined how much they sensed light and how they responded. "By the 50th generation, …and in one of the four colonies of robots … "cheater" robots [appeared] that would lie and tell other robots that poison was food, while they rolled over to a food patch themselves without signalling at all" [24]. How do we conceptualize such a phenomenon in the design of a robot? Ethics in this conceptual picture denotes mapping from ethicthing flow to information flow, as shown in figure 6.

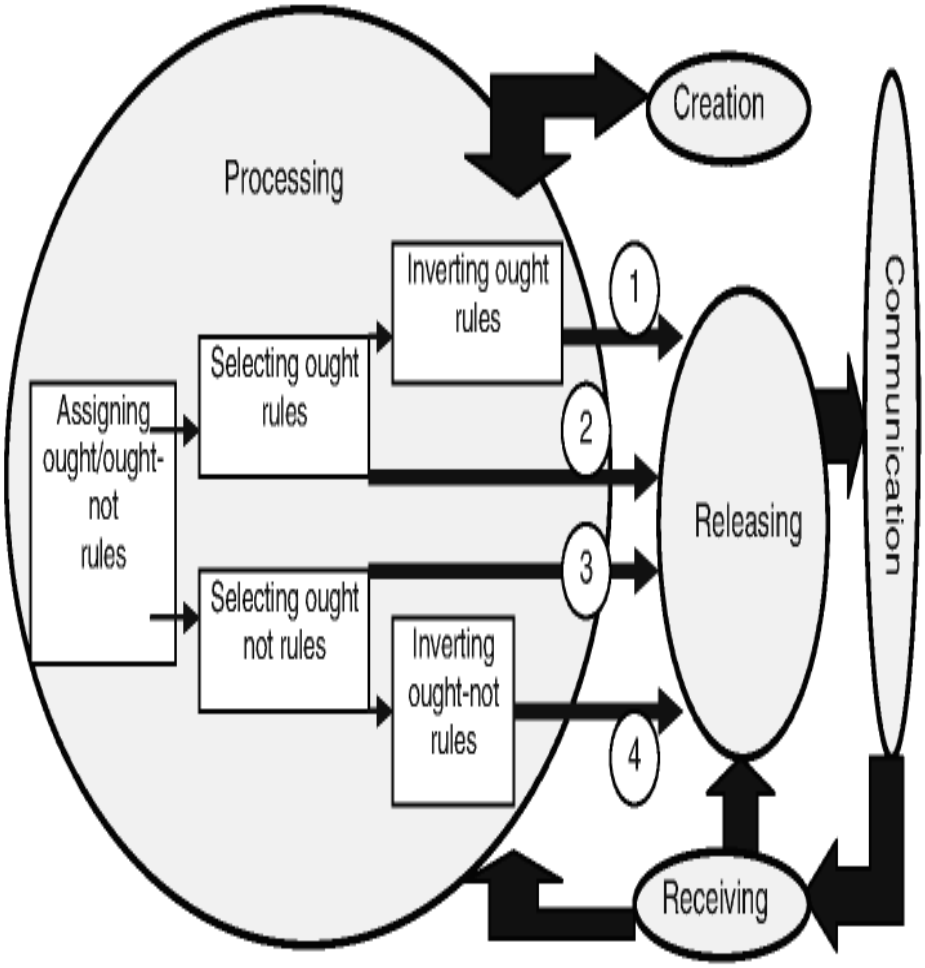

Figure 5. Processes of ought/ought-not in the flow of ethical rules

The figure includes only the relevant stages. We will call different flows that are influenced (i.e., triggered) by the ethicthing flow: application flows. Examples of application flows are information flow and actions flow. The flow system of ethicthings includes receiving, processing, creation, releasing, and communication. It reflects "changes" over time of ethicthings and their flow through:

- creation and receiving of new ethicthings

- triggering the flow of ethicthings by application flows

Thus, while the flow of ethicthings influences application flows (dotted lines in figure 6), application flows (e.g., information, actions, etc.) may influence the ecthicthing flow. For example, when interacting with a real situation, the agent receives information (The sun is rising), and may also receives "values"
(e.g., It is a beautiful scene). Similarly, the valueridden judgment (I ought to forgive) may be interwoven with information (This is a very poor boy trying to steal). Figure 7 illustrates this concept. Accordingly, the relationship between the flow of ethicthings (and values in general) seems to be a very interesting relationship to explore. FM provides a framework for such explorations.

Figure 8 simplifies the mapping between ethical and informational flow of figure 6 in terms of flows that go through inverting and non-inverting processes.Figure 9 (with the large ellipses labeled Ethicthing and information deleted) further simplifies this mapping through identifying possible triggering of mapping between ethical and informational flows as follows:

- In (a) of figure 9, we see that Kant's ethical system, which includes the absolute ethical rule Ought not to lie, eliminates ethical, hence, informational lying by blocking flow that passes through the inverting processes.

- In (b), we see an ethical system that permits informational lying but blocks ethical lying. This is the classic case of "doing without believing."

- In (c), we see the opposite of (b), where the agent believes in Ought to lie, nevertheless, he/she/it tells the truth. It might be that other considerations overrule the conviction of Ought to lie.

In the case of lying robots introduced previously, it is clear that by the 50th generation, new ethicthings were created/ received and adopted (assigned "ought to"). These new ethicthings took control of information and action flows. Our model provides a conceptual picture of different aspects resulting from such a development.

For example, figure 10 conceptualizes the addition of a new robot that represents global ethics, which may be without "actions flow." It monitors the introduction of new ethicthings in the eight original robots and acts accordingly.

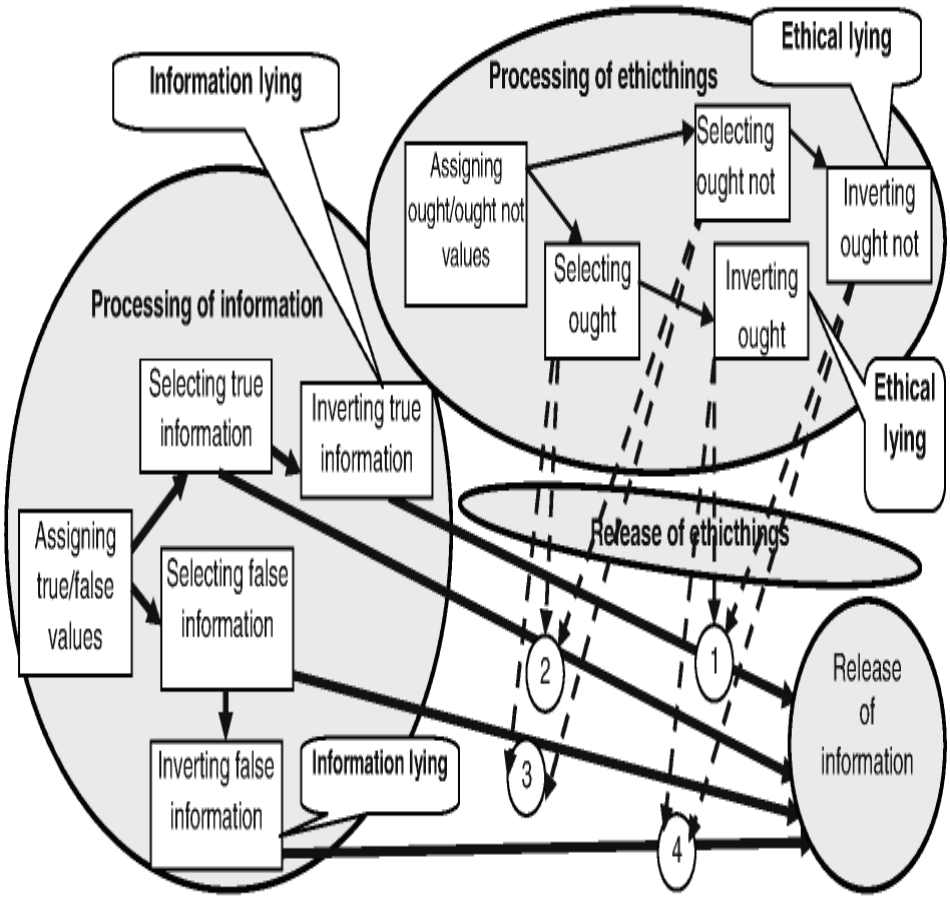

Figure 6. Mapping from ethical flow to information, where certain ethical flow constrains the triggering (dotted arrows) of some information flow

8. Designing artificial agents

The model of ethicthings systems introduced in the previous sections provides templates for ethicsbased behaviors. FM-based modeling can be utilized in designing artificial agent behavior. Consider the first phrase in Asimov's 1st Law [4]:

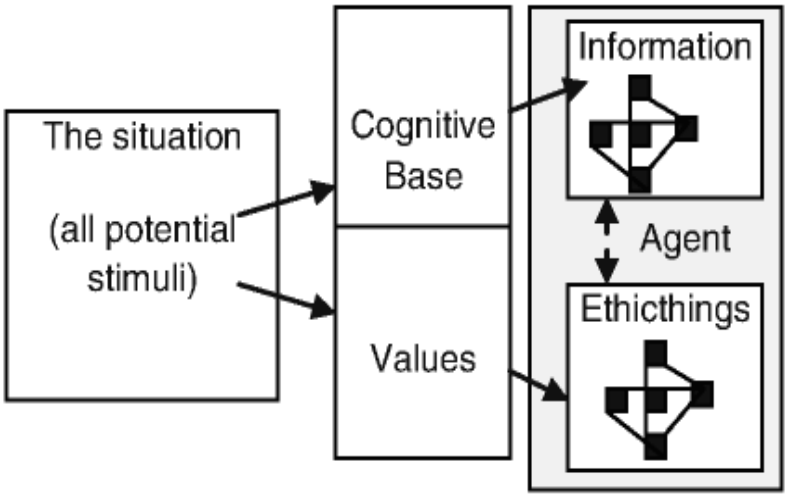

Figure 7. Relationship between ethicthings and information flows with respect to the outside environment of the agent This figure is inspired by a figure in [13], p. 195

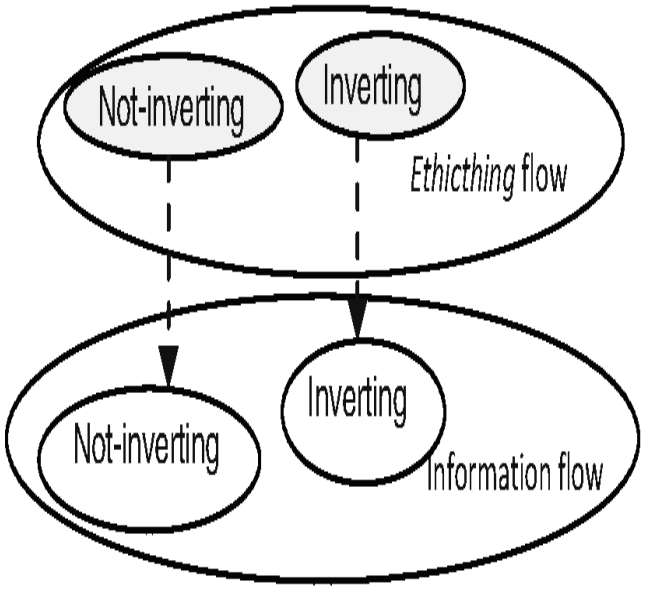

Figure 8. Simplification of mapping between ethics and information flow

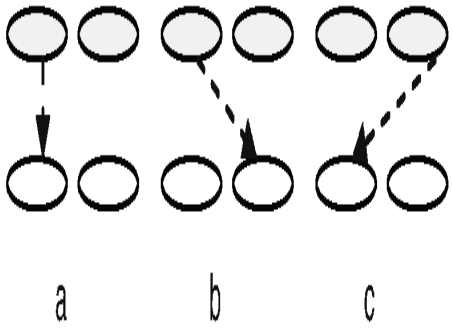

Figure 9. Other cases of mapping

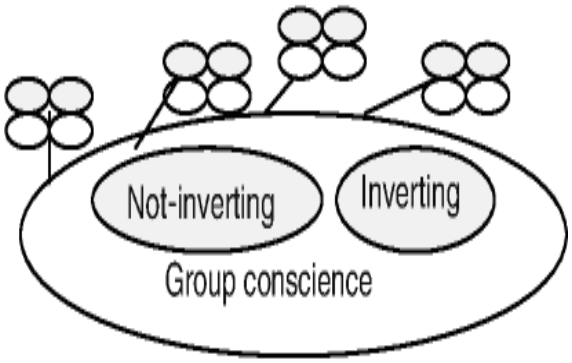

Figure 10. Conscience that monitors the robots' creation and reception of ethicthings

A robot ought not harm a human being. Assume that this rule is received by a robot, and processed to be accepted as part of the robot's beliefs.

Assume that this rule is received by a robot, and processed to be accepted as part of the robot's beliefs. In design of the execution of this rule, the only permitted flow is "not inverting ought-not" as shown in figure 11. The figure shows a partial view of the flows of ethicthings and actions.

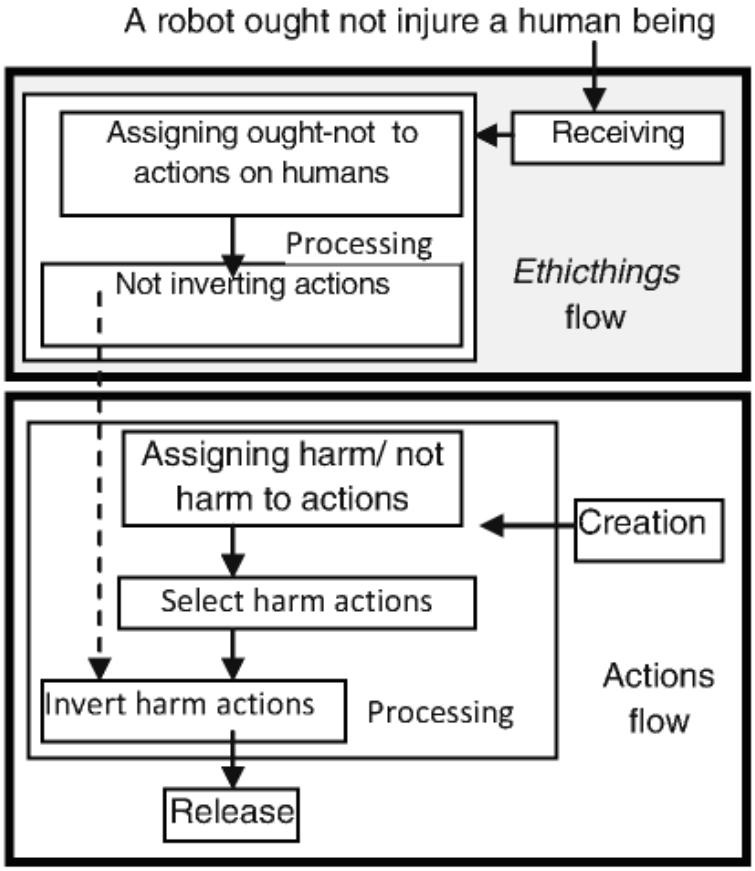

Figure 11. The design of executing the first phrase of Asimov's 1st Law where the law flow triggers (dotted arrow) inverting harm action

Suppose that an action related to a human being is created by the robot. As shown in figure 11, the action flows to the process "Assigning harm/not harm to actions." Suppose that it is assigned to the value "harm." It then flows to "Select harm actions," and by the triggering generated by the ethicthing flow, the flow is directed to "Invert harm actions."

To emphasize the nature of our modeling approach, consider the claim that such a robot procedure can be simply specified in the traditional procedural method, such as:

1. Create an action related to a human

2. If action is harmful then invert it

At the conceptual level, this type of specification mixes two levels: level of instructions and level of rules. The statement: If action is harmful Then invert it is an instruction performed each time an action is executed.
To illustrate the difference between rules (not necessarily ethical) and instructions, consider driving in the United Kingdom and the United States. While driving in the UK, if the robot-driver is not aware of the rule that Driving ought to be on the left side of the street (ignoring learning aspects), then it drives according to the following procedure:

1. Drive the car

2. If on the right side of the road then go to the left side.

The driver needs to be continuously reminded by the instruction: If on the right side of the road go to the left side each time it creates the action of driving. If it is in the USA, then the instruction If on the left side of the road go to the right side is executed upon driving. It is as if a second robot is in the back seat repeatingm this instruction to the driver. The instruction set for actions have to be changed whenever moving between the UK and the USA. This approach mimics the instructional approach.

On the other hand, imagine that the robot-driver "knows" the rule Driving ought to be on the left side of the street when in the UK. This rule is above the actions flow level. The rule level is a watchdog that monitors action and triggers changes in flow. Hence, the driving scenario proceeds as follows:

In actions flow: creation of a driving action

In rulething flow: awareness of the creation of a driving action

In actions flow: assignment of "right" to the action

Rules: awareness of the assignment of "right side of road" to action

In rulething flow: trigger inverting the action to "left side of road"

In terms of the human harm example, the events occur as follows:

In actions flow: creation of a human-related action

In rulething flow: awareness of the creation of human-related action

In actions flow: assignment of "harm" to the action

Rules: awareness of the assignment of "harm" to human-related action

In rulething flow: trigger inverting the action Notice that there is no IF statement in the instructions for actions flow. The flows of actions and rules are simultaneous and synchronized.

In the driving example, the robot driver does not need to execute the IF statement each time it drives. The creation of driving action initiates two flows: flow of actions and flow of processing related rules. The rules have to be changed when moving between the UK and the USA.

This second method is more suitable for conceptualizing ethical systems. The method explicitly separates rules from instructions, which simplify the system design. The conceptual picture is clearer than mixing rules and nonrules. Nonrulesbased flows (e.g., information) are usually larger than rules flows (ethicthings), thus more difficult to change. The two-level structure, where the rules flow takes the role of a watchdog over other flows, seems the intuitive way to position (ethical) rules over other types of activities.

9. Lying as an Action

Lying is a type of action. Hence, anatomizing the notion of lying involves analyzing the nature of action.

Action is typically defined as subjective behavior or activity, as distinguished from mere thought or mechanical behaviors. "Causal models" of action view action as intentions that cause specific actions. Hacker's action theory [12] analyzes human

activity as a goal-directed behavior. Its main components are "acts" regulated by intentions (goals), "actions," the smallest units of cognitive and sensory-motor processes oriented toward conscious goals, and "operations" as components of actions that have no independent goals [11]. According to [11],

> Action Theory deconstructs the process of translating an intention into an action… The information processes of the users "regulate" the types of actions selected… Incoming stimuli are Assigning harm/ not harm to actions Select harm actions A robot ought not injure a human being Not inverting actions with ought not Receiving Ethicthings flow Actions flow Processing Processing Assigning ought-not to actions on humans Invert harm actions Creation Release Figure 11. The design of executing the first phrase of Asimov's 1st Law where the law flow triggers (dotted arrow) inverting harm action. consciously organized by the user and trigger certain actions when the criteria for those actions are met [italics added].

As we have already seen, the notion of triggering is an important element in the flow-based model.

To illustrate the type of models that involve action, consider the distinction between prior intention and intention in action [22]. Figure 12 shows a representation of action involving intention.

The FM can be used to describe lying as an action and its related concepts. We propose generalizing the flow-based description to notions related to action. Action is typically defined as behavior with a goal. According to [15], "an action may involve five aspects: perception, cognition, emotion, volition, and physical or motor performance." Motivation refers to "motives" related to the goal of determined behavior. Personal values are "standards or criteria held by people that effect the evaluative acts in which they are involved" [20]. According to [18], "need" may be conceptualized as "a category of required relationships of the individual with his world." Beliefs are stated as propositions. Desires can be conceived as propositional desires (e.g., I will do something). Goal is defined in terms such as end-states, outcomes, and desirable consequences [14]. These notions can be visualized as flowthings.

To contrast the flow-based approach with other descriptions, again consider Searle's distinction between prior intention and intention in action (figure 12). A possible FM representation is shown in figure 13 [6]. In this case we have two spheres: intentions and movements. We assume that prior intention is stored in the processing stage, though it can be stored in other stages (e.g., receiving). The dotted arrow on the left indicates that some event triggered retrieval of this prior intention to be further processed in order to create intention in action.

This intention in action triggers creation of bodily movement released and transferred to the outside. The resultant description provides a "purified" conceptualization of the semantics of the associations between different types of intention on one hand and bodily movements on the other. A variant of action theory applied to behaviors under volitional control is called reasoned behavior [1]. Inthis conceptualization, intentions compete with each other; hence, the notion of control introduces the ability of the individual to execute the intended action [15]. Planned behavior (such as the type of lying discussed previously) is concerned with factors that influence the formation of intention and emphasizes
the action plan.

Stages of action related to the psychology of a person performing a task were introduced by [17]. The stages of execution comprise the following:

1: Specification of the goal

2: Formulation of intention to do the action

3: Specification of a set of internal commands, an action sequence performed to satisfy the intention

4: Execution of the action sequence

Analyzing the previous descriptions with respect to lying shows that they include the following:

1: A pre-initiation presence of determination of lying

2: An initiation of development of lying

3: A flow that specifies the propositional body of the lie, and methods of delivery (oral, writing, etc.).

4: An execution resulting in the production of a lie

For computer scientists, specification of the sequence of a set of commands and execution of the sequence means control flow. We aim here at a flowbased description of the process of lie production from its inception to realization [6].

Control is usually visualized as a process of input and output. Control is also described as "the process of monitoring activities to ensure that they are being accomplished as planned and correcting any significant deviation" [19]. In UML, control is visualized in the context of the general notion of behavior as follows.

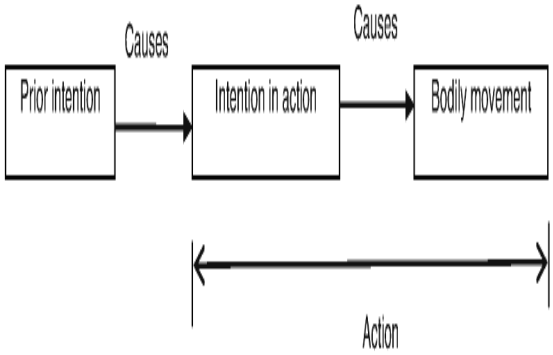

Figure 12. Prior intention, intention, and action [22]

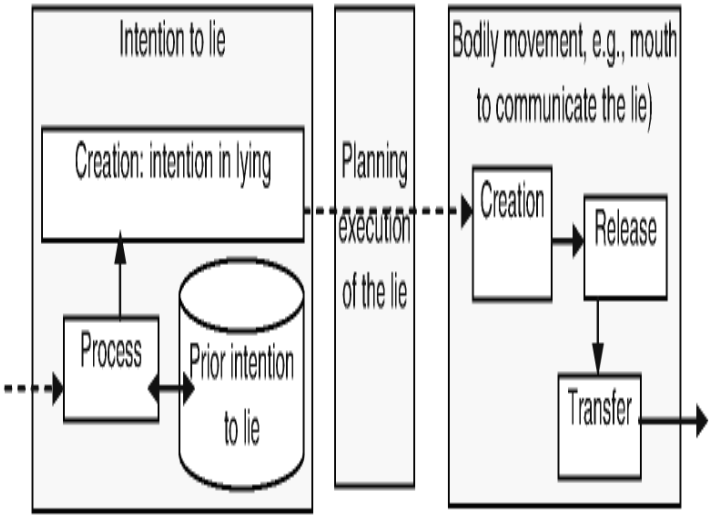

Figure 13. Flow-based Representation of figure 12

> Behavior models, in general, determine when other behaviors should start and what their inputs are... In particular, the UML 2 activity models follow traditional control and data flow approaches by initiating sub-behaviors according to when others finish and when inputs are available. It is typical for users of control and data flow to visualize runtime effect by following lines in a diagram from earlier to later end points and to imagine control and data moving along the lines. Consequently a token flow semantics inspired by Petri nets is most intuitive for these users, where "token" is just a general term for control and data values. [7] (italics added).

Notice how "flow" is qualified by "control and data" and then connected to "token flow" in Petri nets. "Control flow," or "flow of control," is typically described as the order in which statements (of an imperative program), processes, operations, etc. are executed. But does "control" flow?

Little has been written about the concept of *flow*, as discussed in this paper. According to [8],

> The word 'flow' sprang up as the word fluxus in Latin, long before many of us can remember. Its root definition has remained intact, with the primary meaning "to move in a (steady) stream." The cognitive image of a liquid is therefore fused into every metaphor using flow.

The author distinguishes between things that flow (we call these flowthings) and their river beds (we call them flowstreams):

> The sidewalks and isles are the customer's equivalent to a river of asphalt – or dare I imply riverbed of asphalt. Because of

their decidedly stationary and laterally limiting quality, these forms of indoor and outdoor flooring could not be the liquid centre of the metaphor flow, but are rather a channel for which something else of liquid quality will travel [emphasis added].

Then, Casni [8] asks, "What is the riverbed of a cash flow?" Similarly, we ask, what is the flowstream of control (since it is claimed that it flows)? We suggestm that, conceptually, control is itself the flowstream. For example, the instructions (statements) of a computer program flow in and out of the stream-of-control unit. Assuming a sequential order of instruction/statements, figure 14 shows the flow in the control sphere where instructions flow along the stages of the FM model of the control, one after the other. The control sphere refers to the flow of instructions in the FM representation of the control unit.

Control here acts as a machine that is fed instructions/statements that queue to enter the control stream and exit. For example, if program statements are given by the sequence s1, s2, …, sn, the flow can be described as:

– Transfer and receive s1 in the control stream

– Process s1, where s1 is activated

– Release and depart s1

– Transfer and receive s2

– Process s2

– Release and depart s2

– Etc.

The flow, in this example, is the "pure" flow of statements in the control sphere. To achieve modeling of phenomena that begin with intention and end with a physical action, we use FM with mental and physical spheres, as shown in figure 15.

In the mental sphere, we have, first, the goal sphere, which involves creating the goal of the lying action (circle 1 in the figure). In general, the goal may be received when outsiders influence the involved agent and implant in him or her motives to lie. Figure 15 does not show this situation, but, certainly, it is possible to add it to the figure. The goal sphere interacts with other spheres in two ways:

(1) Creating a goal is concurrent with triggering the creation of required steps of commands necessary to achieve that goal (circle 2). That is reflected in figure 14 by creation of these commands and their storage (circles 5 and 6). This amounts to conceiving an ordered set of instructions to lie. An example of a set of these instructions:

- Make introduction, e.g., expressions: "I swear by God," "I am telling you the truth"

- Make the linguistic body (proposition) of the lie

- Decide on the method of delivering the lie: spoken, written, whispering

- Execute post-lying action, e.g., crying, touching

The instruction set is created and stored, ready to be implemented. In analogy, picking a berry from a bush and eating it, for instance, involves moving the hand, grasping the berry, and pulling the hand back toward the mouth. Still, such a plan needs a decision to implement the instructions (implemental intention). These steps sometimes reveal that it is not feasible to accomplish the goal; thus, another goal is created e.g., change the lie). In figure 14, to indicate this possibility, the triggering (dotted arrow) between goals and commands spheres is bi-directional.

(2) Creating a lie triggers the "intention to act" (circle 3), i.e., a decision to execute the sequence of commands necessary to reach the goal of lying. Thus, the process starts at point 3 (circle 4) when a decision is made to lie.

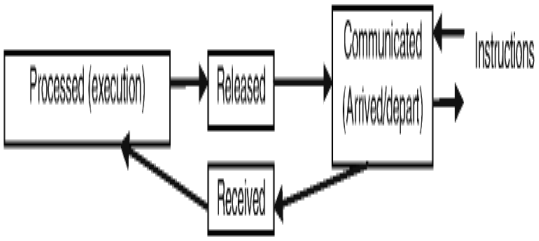

Figure 14. Statements' flow in the control sphere

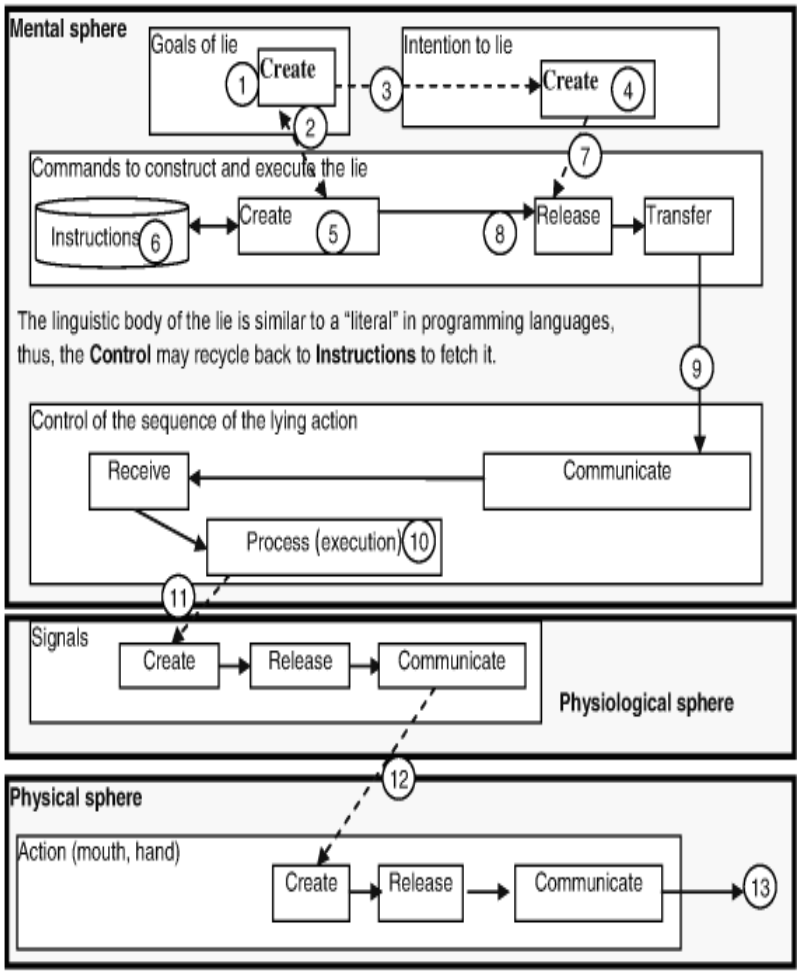

Figure 15. Process involved in creating the action of lying

The creation of that decision (circle 4) triggers (circle 7) the flow of instructions (release – circle 8) to the commands sphere to be executed (circle 9). In the commands sphere, each incoming instruction is processed (executed – circle 10). Execution means triggering the creation of a signal (point 11) that is transmitted to the mouth or hand (physical sphere). This triggers creation of the required bodily movement (circle 12). Execution of the instruction culminates in actual movement of the mouth or hand (circle 13). This process is repeated for all instructions one at a time.

This FM-based description provides a complete map of the sequence of flows involved in lying. It clarifies the control (commands sphere) notion and ties goals to control.

10. Conclusion

The proposed model can be utilized in analyzing ethics (e.g., defining lying and truthfulness in terms of information flow) and design (as demonstrated with respect to robots), and as an educational tool.

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