From Signals to Knowledge and from Knowledge to Action: Peircean Semiotics and the Grounding of Cognition

Eduardo Camargo and Ricardo R. Gudwin
DCA-FEEC-UNICAMP

gudwin@unicamp.br
https://faculty.dca.fee.unicamp.br/gudwin
Introduction

- Philosophy of Mind
  - How the mind works?
  - What happens inside the mind?
  - How mind elements relate to the real world?

- Artificial Intelligence
  - Computational algorithms inspired by different theories on how mind works

- Cognitive Science
  - Scientific theories trying to explain the mechanisms of cognition
  - Integrate findings from different origins:
    - Philosophy of Mind, Artificial Intelligence, Neuroscience, Psychology, Linguistics, Social Sciences
Introduction

Cognition

- Process happening inside the mind, which collects data from the world, using sensors, transforms this data into knowledge, and based on this knowledge and internal agent’s goals, generates a sequence of actions, affecting the world by means of actuators.

Models of Cognition

- Theories of possible ways in which cognition might be happening in actual minds.
- Can be used in order to generate artificial agents, to be used in the context of artificial intelligence.
- Inspiration on the many branches of cognitive science:
  - Philosophy of Mind, Artificial Intelligence, Neuroscience, Psychology, Linguistics, Social Sciences.
The Scope of Cognition

Cognition

Perception

Actuators

Sensors

Environment

Mind

World
The Scope of Cognition

- Perception
- Sensors
- Mind
- Environment
- Cognition
- World
- Action
- Actuators
The Scope of Cognition

- Perception
- Sensors
- Mind
- Environment
- World
- Cognition
- Action
- Actuators
The Scope of Cognition

- Perception
- Cognition
- Actuation
- Mind
- Environment
The Scope of Cognition

- Perception
- Cognition
- Action

- Sensors
- Actuators

Mind
Environment

World
The Scope of Cognition

Knowledge

Perception | Cognition | Action

Sensors | Mind

Environment

Actuators

World
Charles Sanders Peirce (1839-1914)
- American philosopher, father of (Peircean) Semiotics and American Pragmatism
  - “One of the most original minds of the later nineteenth century and certainly the greatest American thinker ever” (Bertrand Russell)
  - “One of the greatest philosophers of all times” (Karl Popper)

Semiotics
- Study of signs and sign processes

Peircean Semiotics
- Sophisticated and complex, with deep philosophical commitments
- Strong technical terminology requiring a great effort of abstraction in order to be properly understood
Elements within the Mind and their Categories

- Aristotle (10 basic Categories)
  - Categories are related to the classes of words
  - Substance; Quantity; Quality; Relatives; Somewhere; Sometime; Being in a position; Having; Acting; and Being acted upon

- Kant (12 basic Categories, 3 for each of 4 modalities)
  - Categories are related to kinds of judgment
  - Quantity (Unity, Plurality, Totality), Quality (Reality, Negation, Limitation), Relation (Inherence and Subsistence, Causality and Dependence, Community), Modality (Possibility, Existence, Necessity)

- Peirce (3 basic Categories)
  - Categories are related to the connectivity between ideas
  - Firstness, Secondness, Thirdness
**Firstness**
- “The mode of being of that which is such as it is, positively and without reference to anything else”

**Idea of Firstness**
- Related to the ideas of potentiality, originality, possibility and independence, randomness, chance, random actions, a feeling not yet converted to reflection, just a glimpse of the reality in the state of pure indetermination;
Peircean Categories

- **Secondness**
  - “The mode of being of that which is such as it is, with respect to a second but regardless of any third”

- **Idea of Secondness**
  - Related to our experience on current space-time, actuality, to reactive actions, to cause-effect relationships, to the experiential reality, to actual facts, to the perceptive consistency without purpose or judgement yet, a binary relation, a cartesian pair
Peircean Categories

- **Thirdness**
  - “The mode of being of that which is such as it is, in bringing a second and third into relation to each other”

- **Idea of Thirdness**
  - Related to mediation, to law or habit, to thought and continuity, to purpose and judgement, to the idea of representation, to the sign itself
Sign or Representation

Sign (or Representamen)

- “A Sign, or Representamen, is a First, which stands in such a genuine triadic relation to a Second, called its Object, as to be capable of determining a Third, called its Interpretant, to assume the same triadic relation to its Object in which it stands itself to the same Object. The triadic relation is genuine, that is, its three members are bound together by it in a way that does not consist in any complexus of dyadic relations”
Ideas (elements of the mind)

- Encoded within the mind as signs
- Can be connected to other ideas, forming more complex ideas
  - Can be simple or composed
- Can be of different types
- Can express different aspects of reality
  - Possibilities (Imaginations, Speculations, Hypothesis, Plans for the future, Exploration of scenarios): firstness
  - Actuality or Existence (Things that are really happening or really happened): secondness
  - Laws (Categories, Types, Habits of Behavior, Patterns, Learning Algorithms): thirdness
- Can describe reality by different means
  - Qualities or Properties (firstness)
  - Things (secondness)
  - Categories of Things/Qualities (thirdness)
The Three Worlds of Ideas

- **Actuality**
  - World of Existence

- **World of Possibilities**

- **World of Laws**

- **Agent**
One Instance of the Three Worlds

- World of Things
- World of Senses
- World of Categories

Agent

direct access

presumed

presumed
Classification of the Signs

Firstness
- Qualisign
- Icon
- Rheme

Secondness
- Sinsign
- Index
- Dicent

Thirdness
- Legisign
- Symbol
- Argument
Classification of the Signs

Firstness
Secondness
Thirdness

Rhematic Iconic Qualisign
Rhematic Indexical Sinsign
Dicent Indexical Legisigns
Accessing the World of Senses

1. Transduction
   - Environment
   - Agent
   - Signal set
   - Transduced signal on a material substrate
     - Chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent
   - Possible repositioning by the interpreter's mind

2. Intensity
   - Number

3. Position/Orientation
   - (x, y, z, roll, pitch, yaw)

Possible semiosis

Interpreter's mind

Qualisign

Possible repositioning by the interpreter's mind

Properties

Presumed existent (Dynamic object)

Necessities (Natural laws)
Accessing the World of Senses

1. Transduction
   - Environment
   - Agent

Properties
- Presumed existent (Dynamic object)
- Necessities (Natural laws)

Signal set

Sensor

Transduced signal on a material substrate
chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

2. Intensity (number)

3. Position/Orientation (x, y, z, roll, pitch, yaw)

Possible repositioning by the interpreter's mind

Possible semiosis

Physical Property

Interpreter's mind

Qualisign
Accessing the World of Senses

1. Transduction
   - Environment
   - Agent
   - Sensor
   - Transduced signal on a material substrate
   - Possible semiosis
     - Chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

2. Intensity
   - (number)

3. Position/Orientation
   - (x, y, z, roll, pitch, yaw)

Possible repositioning by the interpreter's mind
Accessing the World of Senses

Properties

Presumed existent (Dynamic object)

Necessities (Natural laws)

Signal set

Sensor

Transduced signal on a material substrate
chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of de agent

1. Transduction

2. Intensity (number)

3. Position/Orientation (x, y, z, roll, pitch, yaw)

Possible repositioning by the interpreter's mind

Possible semiosis

Qualisign

Interceptor's mind
Accessing the World of Senses

1. Transduction

Properties
Presumed existent (Dynamic object)

Necessities (Natural laws)

Signal set
Sensor

2. Intensity
(number)

Transduced signal on a material substrate
chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

Possible repositioning by the interpreter's mind

3. Position/Orientation
(x, y, z, roll, pitch, yaw)

Possible semiosis

Signals (data)

Interpreters mind

Qualisign

Possible repositioning by the interpreter's mind
Accessing the World of Senses

1. Transduction
   - Environment
   - Agent

2. Intensity
   - Signal set
   - Sensor
   - Transduced signal on a material substrate
   - chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

3. Position/Orientation
   - (x, y, z, roll, pitch, yaw)

Possible repositioning by the interpreter's mind

Possible semiosis

Knowledge

Interpreter's mind

Necessities (Natural laws)

Presumed existent (Dynamic object)
Accessing the World of Senses

1. Transduction
   - Environment
   - Agent
   - Signal set
   - Transduced signal on a material substrate

2. Intensity
   - Environment
   - Agent
   - Sensor
   - Possible semiosis
     - chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

3. Position/Orientation
   - Environment
   - Agent
   - Possible repositioning by the interpreter's mind
     - Possible repositioning by the interpreter's mind

Knowledge

Properties
- Presumed existent (Dynamic object)
- Necessities (Natural laws)
Guessing the World of Things

Properties

Presumed existent (Dynamic object)

Necessities (Natural laws)

Signal set

Sensor

1. Transduction

Environment

Agent

Transduced signal on a material substrate

chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

2. Intensity (number)

3. Position/Orientation (x, y, z, roll, pitch, yaw)

Possible repositioning by the interpreter's mind

Possible semiosis

Qualisign

Knowledge

Interpreter's mind
Sensor Repositioning (Focus of Attention)

Presumed existent (Dynamic object)

Properties

Necessities (Natural laws)

Signal set

Sensor

Transduced signal on a material substrate

1. Transduction

Environment

Agent

2. Intensity (number)

Chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

Possible repositioning by the interpreter's mind

3. Position/Orientation (x, y, z, roll, pitch, yaw)

Possible semiosis

Qualisign

Knowledge

Interpreter's mind
Guessing the World of Things

Properties

Presumed existent (Dynamic object)

Necessities (Natural laws)

Signal set

Sensor

Transduced signal on a material substrate

chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

1. Transduction

Environment

Agent

2. Intensity (number)

3. Position/Orientation (x, y, z, roll, pitch, yaw)

Possible repositioning by the interpreter's mind

Possible semiosis

Qualisign

Knowledge

Interpreter's mind
Guessing the World of Categories

1. Transduction

Environment Agent

Signal set

Sensor

2. Intensity (number)

Transduced signal on a material substrate
chemical-electric sparks, electric pulse, discrete numbering, etc, depending on the nature of the agent

3. Position/Orientation (x, y, z, roll, pitch, yaw)

Possible repositioning by the interpreter's mind

Possible semiosis

Qualisign

Knowledge

Interpreter's mind

Presumed existent (Dynamic object)

Properties

Necessities (Natural laws)
Sensors as Sources of Iconic Information

Icons
- Signs that are connected to their objects by having some sort of similarity or analogy to them
- Can be of three different types:
  - **Images** (firstness): icons which present in themselves the same properties as their objects.
  - **Diagrams** (secondness): icons which in their parts present the same state of affairs as the parts of their objects.
  - **Metaphors** (thirdness): icons which hold in themselves another kind of parallelism, e.g. some sort of analogy to their objects.

Sensors
- Can be understood as metaphors to the property they measure, by sharing with them the same numerical intensity as these properties, i.e., they are in a relation of analogy to them
From Signals to Knowledge

**Sensors**

- Provide the means for directly generating iconic signs of the physical properties they measure.
- The numeric measurings provided by the sensor are in a relation of direct analogy to the physical properties.
- By associating this number to the origin in a particular sensor, we know that this number refers to a particular physical property, which is the property the sensor is able to measure.
- Besides that, the information regarding the sensor position and orientation, provides the required data for being the substrate that turns these signals into a sign, becoming knowledge for the agent.
- In becoming full icons, they are put into a direct connection to the properties they represent. This connection is ensured by the way the sensors are constructed, as a transductor.
Index

- Signs that are connected to their object by forcing the attention to a particular object, different from themselves, without describing it, like e.g. a demonstrative or relative pronoun, or in the case of a direct physical connection between the sign and the object, which can be used to draw attention to it
  - Attention mechanisms are used to drive the interpreter attention to another sign (e.g., an icon, a symbol or another index), which in the sequence will be used for discovering the original sign’s object
  - Attention is changed by moving the sensors position/orientation

Icons and Indexes are both called natural signs

- Because they cannot be dissociated to their object
- The connection to their objects is embedded by nature

The real objects are always inaccessible to an interpreter

- The closest the interpreter can be of an object is always an icon of it
Using Different Kinds of Signs to Make Sense of the World

Firstness - Quality - Possibility - Background

Secondness - Actual existent - Fact - Figure

Thirdness - Necessity - Law - Habit

Laws of instantiation
Continuous
Classification

Laws of coding
Discrete
Consolidation

Laws of signification
Continuous/Discrete
Learning
Meta-laws
Using Different Kinds of Signs to Make Sense of the World

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Laws of instantiation
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Learning
Meta-laws

Possible Properties

Figure
Impression
Something

Rhematic
Iconic
Qualisign

Atention
Apprehension
Other thing
Composition
Expression (Judgement)
Episode

Rhematic
Indexical
Sinsign

Dicent
Indexical
Sinsign

Rhematic
Symbolic
Legisign

Dicent
Symbolic
Legisign

Argument
Symbolic
Legisign

Rhematic
Iconic
Sinsign

Rhematic
Indexical
Sinsign

Rhematic
Symbolic
Legisign

Dicent
Indexical
Sinsign

Argument
Symbolic
Legisign

Possible
Properties

Firstness - Quality - Possibility - Background
Using Different Kinds of Signs to Make Sense of the World

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- Iconic
- Qualisign
- Sinsign
- Legisign
- Argument

Laws of instantiation
Continuous
Classification

Laws of coding
Discrete
Consolidation

Laws of signification
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Background

Sensed Property

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Impression
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Using Different Kinds of Signs to Make Sense of the World

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Laws of instantiation
Continuous
Classification

Laws of coding
Discrete
Consolidation

Laws of signification
Continuous/Discrete
Learning
Meta-laws
Using Different Kinds of Signs to Make Sense of the World

- **Firstness** - Quality - Possibility - Background
  - Rhematic
  - Iconic
  - Qualisign

- **Secondness** - Actual existent - Fact - Figure
  - Rhematic
  - Iconic
  - Sinsign
  - Indexical

- **Thirdness** - Necessity - Law - Habit
  - Rhematic
  - Symbolic
  - Legisign
  - Dicent

**Legislation**
- Laws of instantiation
- Continuous/Discrete
- Classification

- Laws of coding
- Discrete
- Consolidation

- Laws of signification
- Continuous/Discrete
- Learning
- Meta-laws

**Example**
- Figure
  - Impression
  - Something

- Attention
  - Apprehension
  - Other thing

- Composition
  - Expression (Judgement)
  - Episode
  - Background

**Thing Type**
- Rhematic
  - Iconic
  - Legisign

- Rhematic
  - Indexical
  - Legisign

- Dicent
  - Symbolic
  - Legisign

- Argument
  - Symbolic
  - Legisign
Using Different Kinds of Signs to Make Sense of the World

Firstness - Quality - Possibility - Background

Secondness - Actual existent - Fact - Figure

Thirdness - Necessity - Law - Habit

Laws of instantiation
Continuous/Discrete Classification

Laws of coding
Discrete Consolidation

Laws of signification
Continuous/Discrete Learning Meta-laws
Using Different Kinds of Signs to Make Sense of the World

Firstness - Quality - Possibility - Background

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Laws of instantiation
Continuous
Classification

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Continuous/Discrete
Learning
Meta-laws
Using Different Kinds of Signs to Make Sense of the World

Firstness - Quality - Possibility - Background

Secondness - Actual existent - Fact - Figure

Thirdness - Necessity - Law - Habit

Laws of instantiation
Continuous Classification

Laws of coding
Discrete Consolidation

Laws of signification
Continuous/Discrete Learning
Meta-laws

Symbol to Other Thing Around (e.g. word)
Using Different Kinds of Signs to Make Sense of the World

Firstness - Quality - Possibility

Secondness - Actual existent - Fact - Figure

Thirdness - Necessity - Law - Habit

Laws of instantiation
Continuous
Classification

Laws of coding
Discrete
Consolidation

Laws of signification
Continuous/Discrete
Learning
Meta-laws
Using Different Kinds of Signs to Make Sense of the World

Firstness - Quality - Possibility - Background

Secondness - Actual existent - Fact - Figure

Thirdness - Necessity - Law - Habit

Laws of instantiation
Continuous Classification

Laws of coding
Discrete Consolidation

Laws of signification
Continuous/Discrete Learning Meta-laws
Using Different Kinds of Signs to Make Sense of the World

Firstness - Quality - Possibility - Background

Secondness - Actual existent - Fact - Figure

Thirdness - Necessity - Law - Habit

Laws of instantiation
Continuous Classification

Laws of coding
Discrete Consolidation

Laws of signification
Continuous/Discrete Learning Meta-laws

Symbol to Episode (sentence or phrase)
Using Different Kinds of Signs to Make Sense of the World

Firstness - Quality - Possibility - Background

Secondness - Actual existent - Fact - Figure

Thirdness - Necessity - Law - Habit

Laws of instantiation
Continuous
Classification

Laws of coding
Discrete
Consolidation

Laws of signification
Continuous/Discrete
Learning
Meta-laws

Learning Rule

Figure
Impression
Something

Atention
Apprehension
Other thing

Composition
Expression (Judgement)
Episode

Rhematic
Iconic
Qualisign

Rhematic
Indexical
Sinsign

Dicent
Indexical
Sinsign

Rhematic
Symbolic
Legisign

Dicent
Symbolic
Legisign

Rhematic
Iconic
Legisign

Rhematic
Indexical
Legisign

Rhematic
Symbolic
Legisign

Rhematic
Symbolic
Legisign

Rhematic
Symbolic
Legisign
From Knowledge to Action

- **Semiosis or Sign Process**
  - Process by means a sign is interpreted, generating a new sign, called its interpretant

- **Degenerate kinds of Interpretation might lead to**
  - Three kinds of Interpretant
    - **Emotional Interpretant**: Interpretant is a feeling
    - **Energetic Interpretant**: Interpretant is an action
    - **Logic Interpretant**: Interpretant is a new sign

- **The Path from Knowledge to Action**
  - Takes place when the interpretant of the sign is an energetic interpretant
Three Kinds of Energetic Interpretants

- Random Actions (firstness)
  - Used during exploratory behaviors
- Reactive Actions (secondness)
  - Actions directly generated by a particular set of stimuli
- Goal-based Actions (thirdness)
  - Goal: future state the agent is supposed to reach
  - Plan: representation of a set of actions, which should lead the agent to its current state to the desired goal state

Agent Behavior

- Composed of sequences of actions of these three types
Conclusion

Peircean Semiotics

- Provides an extensive set of concepts for grounding cognition into a solid philosophical theory
- Provides many insights, which might be useful for the construction of artificial intelligent agents
- Has a rich typology of sign types, which extends far beyond standard approaches to purely symbolic Artificial Intelligence and also more recent approaches trying to fill the symbolic/numeric gap, as e.g. neural networks
  - Symbols can be grounded into indexes (using attention mechanisms) and icons (creating mental simulations), which creates the opportunity for artificial agents to have full understanding of natural language sentences and other types of communication
- There is much more than the 10 sign types: this is just the beginning ...