Abstract: - This paper describes some concepts which are important for the creation of autonomous agents capable of growing up. Growing up means that living systems, starting from a pre-structured set of functions, develop competence to better adapt to the environment all life long, from childhood to maturity. A living artefact grows up when its capabilities, abilities/knowledge, shift to a further level of complexity, i.e. the complexity rank of its internal capabilities performs a step forward. We want to define an architecture containing mechanisms which play the same role for autonomous agents as the mechanisms that make humans so successful [1]. In the attempt to define an architecture for autonomous growing up agents, we have been investigating the abstraction process in children as natural parts of a cognitive system. We studied deliberative and non-deliberative (emergent) mental adaptive and growing up mechanisms. A list of functional requirements based on these concepts is then proposed.

Key-Words: - growing up, living artifacts, abstraction mechanisms, intelligent architecture, adaptable agents, epigenetic robotics

1 Introduction
The Darwinian gradualist concept of evolution considers development as the cumulative result of a large number of very small changes that occur over a long period of time. This gradual continuous process is driven by the blind process of natural selection. Successful biological adaptation was fuelled by a process of random variation and mutation. Highly homogeneous species have limited chances of survival if the environment changes beyond certain bounds.(Fig.1a)

Vested or acquired features keep the system from mutation. This equilibrium lasts until the system is no longer able to assimilate demands for change into its existing structure.

The artificial neural network models are defined within this paradigm. Each ANN configuration optimizes the learning of a specific function[21].

![Image](a) ![Image](b)

Fig. 1 Development process: (a) Darwinian continuous learning theory ,(b) stage theory of development: it reflects a punctuated equilibrium phenomenon

The stage theories of development reflect a discontinuous qualitative change from one stage to another[17]. Each person or living being develops by means of a successive, mostly invariant, sequence of stages. Each stage is characterised by being more complex than the preceding one and having in its structure subsumed all the cognitive, relational and organised structures of the previous stages (fig.1b).[2]

In humans the stage sequence is, in some way, always affordable and flexible: a person in a later stage is able to afford to a schemata belonging to an earlier stage.

The transition between stages, denoting the growing up process, is possible through an assimilation and accommodation dynamic: the assimilation represents the system's bias to stability. The system maintains itself stable until environment, events and different circumstances will allow it. The sequence of stages derives from the integration of several subprocesses. Each subprocess is unsynchronized with development in other subprocesses [7]. In individual development, these subprocesses would include perception, cognitive complexity, emotions, value system, motivations, experiences and social interactions.

2 Growing up in living beings and in artifacts
Over the last decade, a number of researchers have suggested a developmental perspective on artificial intelligence and robotics. The ultimate shared goal among them seems to be the idea of bootstrapping high-level cognition through a process in which the agent interacts with a real physical environment over extended periods of time [14]. One of the fundamental methodological assumptions is that cognition is embodied, which means that it arises from bodily...
interactions with the world and that it is continuously meshed with them [12]. In other words, thinking emerges from real life experiences, from sensory-motor coordinated interactions, and from exploration of the surrounding environment.

A great deal of current research work in robotics and autonomous systems is still focused on getting an agent to learn to do some task such as recognizing an object or going to a specific place. The learning process may be supervised, unsupervised or a process of occasional reinforcement, but the whole aim in such work is to get the robot to achieve the task that was predefined by the researcher.

Biologically motivated intelligent computing has in recent years been successfully applied to solving complex problems. The process or plant to be controlled is often unknown and even after identification; its characteristics may change due to aging, wear and tear, etc. Furthermore, there are various noises and disturbances present in the system. New approaches where intelligence is not given to the system from outside, but is acquired by the system through learning, have proven much more successful.

A developmental intelligence for growing up robots must be able to generate automatically representations for unknown knowledge and skills. Like humans and animals, the robots must learn in real time while performing "on the fly"[8].

The next logical step along the road towards truly autonomous robots that can dive in unpredictable environments is to investigate how one might design robots that are capable of `growing up' through experience.

A living artefact grows up when its capabilities, abilities/knowledge, shift to a further level of complexity, i.e. the complexity rank of its internal capabilities performs a step forward. Steels in [22] claimed that the new level can “slave” the level or the levels below, or it is possible to see a kind of co-evolution towards greater complexity. Growing up means that living systems, starting from a pre-structured set of functions, develop competence to better adapt to the environment all life long, from childhood to maturity.

By growing up we mean that a robot starts with only some basic skills such as an ability to move about and an ability to sense and react to the world (such as trying to avoid obstacles), but in the course of time it develops new skills that were not entirely engineered into it at the start [19].

There are many skills that a robot might acquire that are uninteresting or unproductive for observers or even unrecognizable, such as the ability to percept, to classify objects, places and situations that are not intelligible for human beings. We feel that higher-level skills should be skills that are manifested on appreciably longer time-scales than lower-level ones. The ability to recognize a certain location, for example, involves internal and external activity over a longer time scale than the ability to avoid collisions. Growing up should be more than a matter of prolonged supervised learning or reinforcement learning.

Growing up is an emergent mechanism. This means that it cannot be reduced to its parts. In other words, it exists at one level of structure but cannot be fully explained in terms of structure at a lower level. The dynamic systems approach [5] attributes the emergence of complex cognitive skills (e.g., finding objects, imitation, symbol grounding) to basic processes of attention and pattern learning in sub-symbolic distributed networks. Robotic models of development can play an important role in specifying the minimal preferences, faculties, and processes needed for a skill to emerge.

3 Problem Formulation

The exploratory behavior seems to “shape” the information flow in various sensory channels. The exploitation of the data for learning, and the derivation of the conditions under which a growing up artefact can learn new categorization behavior, while maintaining the stability of existing ones, is a topic of great interest. Human infants, for instance, exhibit a wide range of exploration strategies: mouthing, banging, fingering, scratching, squeezing, waving, and listening [10]. Through its own action, living beings are able to generate stable sensory patterns in different sensory channels, which can be exploited to form cross-modal associations. In humans these associations seem to be a basic prerequisite for concept formation [23], which is of fundamental importance for what might be called high-level cognition.

Some psychological theories call the growing up process insight, others refer to it as complexity growing and others speak about creativity. These are all different points of view of the same process consisting of a step toward the enlargement of the internal knowledge map. In the language research field, abstraction is an example of growing up. A better understanding of this mechanism is fundamental for the knowledge of what really is intelligent behaviour.

From the knowledge level, i.e. processing and analysis of input data coming from sensors, growing up introduces a new level of comprehension of the objects in relationship to other known objects. The new representation of objects can be more abstract and it strikes roots in the experience connected to a preceding familiar object.

In previous approaches, abstraction has been frequently defined as a mapping between languages. Our main departure from this view is that abstraction is, originally, a mapping between views of the world, and that the
modifications of the structure and of the language are side-effects, necessary to describe what happens at the level of the perceived world. Within the defined framework, we analyze how the abstraction process can be realized by means of a set of operations, and we try to analyze the path that abstraction mappings should follow in order to be useful for being implemented as an architecture for a living artefact that grow up. In Machine Learning, abstraction has been used by Knoblock [11] to learn high level operators in hierarchical planning, by Drastal, Czako and Ratz[4] to learn concepts in propositional logic, and by Zucker and Ganascia[26] to learn concepts in predicate logic. Giordana and Saitta [6] provide a discussion about the differences between generalization and abstraction in learning. There are also significant efforts that have been devoted to the “shift of bias”[25], a problem related to abstraction. This problem deals with the modification of the language used to represent the learning examples and the concepts. Many approaches follow the methodology called constructive induction, which tries to augment the initial language with newly invented features [13,24]. These studies set aside any consideration on the way the subject are involved in the process.

In this paper we propose a perspective on the analysis of the process of abstraction, originating from psychology. In human being this concept representation deals with entities belonging to different levels. The abstraction is not something that one experienced at a particular time in the concrete world, but it captures the essence of many concrete experiences. Abstraction is the result of a complex cognitive activity that leads to a growing up in knowledge, in mapping of the environment, in progression to language acquisition and production. It is quite easy to imagine what is the process that occurs, it is quite difficult to understand how this process starts and goes ahead.

But how does this process happen in nature, what kinds of procedures do people activate to turn up the abstraction? What mechanisms are triggered off?

4 The experiment

We tried to find out which mechanisms are adopted by living beings while cognitively growing-up through an experiment on human being. We studied the modalities through which pre-school children turn up the meaning of a metaphor hidden in common idiomatic sentences in their native language. We chose children of this age because, at their level of cognitive development, they are not supposed to be able to build an abstraction. We carried out this experiment in an infant school in the Genoese Municipality, which had a “Sea Laboratory” where children were accustomed with some sea animal names and with some of their characteristics, but not with the senses of the idiomatic sentences. Forty-two phrases have been proposed to about eight work-groups, of nine to ten children each, asking for their abstracted meanings. After a preliminary period of “brainstorming”, during which the free creative associations were prevalent, we addressed children’s attention towards the individuation and to the further comprehension of the metaphor meaning.

The process has been recorded and then we analyzed the answers. Collective speech have been analyzed to compensate the individual differences.

When an unknown new sentence has been proposed, an attention filter selecting only “salient” key words, was activated. This filter is a function of motivation, affective relationships, value systems, emotions, experiences, knowledge system etc. When the children realized that in the proposed sentences there were some contradictions in comparison with the script of their concrete knowledge, at first, they tried to apply different strategies to reach an acceptable internal configuration. The emotion (affective) filter plays a very big role in driving the choice of the investigative/creative procedure. Children reach the abstraction through the combination/integration of different subprocesses.

5 Results

Underlying any source of experience there is the world, where concrete objects (the “real things”) reside. However, the world is not really known, because we only have a mediated access to it, through our perception. Then, what is important, for an observer, is not the world in se, but the perception that s/he has of it. At this level the percepts “exist” only for the observer and only during their being perceived. Their reality consists in the “physical” stimuli produced on the observer. In order to let these stimuli become available over time, they must be, first of all, memorized into an organized structure. Abstractions are not only grounded in perceptual experience, and retaining something of the “perceptual character” of the experiences of which they were derived, but they are also product or reasoning or creative though. The child disclosure are driven by motivations and emotions. Mechanisms involved in this cognitive evolution could be resumed as follows.

- When an unknown idiom is suggested, the first procedure is to verify that the sequence of words can exist within the internal script called to mind from the sentence.
- If an input sentence can be led back to the reference script, then it is accepted. The child adapts the new information to the previous knowledge, avoiding the cognitive effort of abstraction.
If within the scripts there are no acceptable solutions, the children carry out many different strategies. The children try to solve the current problem by using the knowledge structures stored in their working memories. If the problem cannot be solved, the information processing mechanism backtrack and another set of procedure are tried. If the problem cannot be solved with any possible set of procedure, the children start another set of association of words. This procedure is repeated until a solution is found. As shown in figure 2, the selected keywords are processed following different subprocesses based on the children concrete level of knowledge.

Children learnt to contextualise their concrete definition. They built stories and contests as explicative processes where they can easily insert the chosen keywords. They proposed many alternative solutions justified by fantastic stories or validated by reminiscences connected in some way with the sentence. Children activated the following procedures:

- Emotional reference: Children mediate with their affective implications. They build stories that try to give meaning to phrases, driven especially by the affective/emotive point of view.

**ABSTRACTION**

Fig. 2: Set of processes actuated in growing up phase
• Psychomotor answers (deixis, drawings, etc.). Ignoring a verbal answer children tried to express their filling through gestures or movements. Children try to represent through their body what they could not interpret. This behaviour open a big question about the perception of the proper body in artefacts.

• Assimilation and localization. Children try to integrate the unknown situations within their reality or they try to build a coherent fantastic reality).

• Sensorial similarities: children keep explanations as close as possible to their sensorial perceptions. The sensorial modality most used was the visual sensors, followed by the auditory one. It seems that children have the habit to store in their mind most single information under images.

• Knowledge database (synonyms, functional similarities). They try to search similarities for chosen keywords at a more abstract level of knowledge. They search assonance and known synonyms in their vocabulary. They decide that object with similar functions are equal.

• Children tried to give “grammatical” definitions to the novel metaphorical inputs, concentrating on the sense of the sentence and not on the referent. The interaction, the non linear combination and the integration of these sub processes leads to the emergence of abstracted concept learning.

6 Suggestion for an architecture for a robot that grow up

Our experiment results in some consideration for a robot architecture. It suggests that an efficient developmental architecture should have a hierarchy of basic boxes able to process in parallel different aspects of knowledge. To let the 'growing up' phase to emerge, the system architecture should be able to process a combination of different paths in an internal representation.

To be able to grow up a robot should have a large set of different sensors. For each set of sensor signals there should be a number of characteristic extractor (by using different signal processing techniques like Artificial Neural Networks supervised and unsupervised, isomaps, genetic algorithms, chaotic signal characterization, fft etc)

Information in memory should be stored in such a way that the sensorial perspective should be respected. Children scanned memory by using images, sound and emotions as index. Their memories were elicited from similar characteristics (i.e. colours, shapes, dimension, position) or from similar labels. Words with similar sounds were associated to the same meaning. Children used different types of memory: short term memory and long term memory, procedural memory, episodic memory.

They built many cause-effect relationship between stories and words. By generating motivational states that simulate future needs, anticipatory planning has been made possible [8]. Only a part of the input was processed. The attention was a function of many variables. Their previous experiences, their mood, their values, their emotions, their motivation their drive, their goal were fundamental trigger for the choice of the words to be processed.

The emotion world seems to be driving each level and it seems to be involved in each information processing box. Some papers on controllers based on emotional learning have shown very good robustness and uncertainty handling properties [15, 18].

As confirmed in [1], whether called emotional control or merely an analog version of reinforcement learning with critic (evaluative control), these methods should be increasingly being utilized by control engineers, robotic designers and decision support systems developers and yielding excellent results. Although, for a long time, emotion was considered as a negative factor hindering the rational decision making process, the important role of emotions in human cognitive activities is progressively being documented by other psychologists [16,9].

Motivation, drive, value system and emotions are very difficult to separate: they are strongly related with very strong feedback each other. The motivation is related to some well known variables which include epistemic needs (needs of structure, for desired outcome), values, goals, and mood. Motivational system maintains a connection between actual state and next step. Another suggestion that come out from the experiment is that human being do not act according to the objective situation, but on the basis of their "own perception of the situation". Since this has a major impact on the resulting behavior, a minimal cognitive apparatus performing characterization and/or classification using the robot's values should be provided. There is no need to produce a complete world view by designing a complex ontology, only the most important decision criteria should be provided.

Finally, the combination –integration step giving the abstraction emergence can show a chaotic behavior as suggested in [20] allows a workspace scanning more efficient than an algorithm for the random walker

7 Conclusion

In this paper, we underlined some of the most important characteristics of growing up behavior, which we think are crucial to the creation of realistic living artefact able to grow up t, and we have tried to identify some useful requirements. As the complexity of living being is much higher then the complexity of actual artefacts, only few experiments can be done, nevertheless the increase of this perspective is very important. From one hand, psychologists can provide the detailed empirical findings and theoretical generalisations
that can guide the implementations of robotic systems capable of cognitive development. On the other hand, these implementations can help in clarifying, testing, and even developing psychological theories, which, due to the complexity of the interaction processes involved, often cannot be exhaustively tested [3]. Robots can be used to instantiate and investigate models, originating from developmental psychology, and it is necessary to design robotic systems with a better autonomy, adaptability and sociability by applying the insights gained from the ontogenetic development studies.

Psychological experiments can provide rich and subtle accounts of infant behaviour as it changes with age, but it is more difficult to track and describe internal changes. Robotic models permit us to correlate the model’s changing behaviours in real time and space with all changes in internal representations and processes shown.

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