Abstract

Intelligence and emotions differentiate humans from animals. Emotion is part of a persons behaviour and certain feelings can affect his/her performance, emotions can even prevent a person from producing an intelligent outcome. Therefore, when a computer aims to emulate human behaviour, not only should this computer think and reason, but it should also be able to show emotions. This paper presents a review of recent research that shows the importance of the emotions in human intelligence. This paper also presents the research that has been carried out into the incorporation of emotions to intelligent systems, how a computer can show affections and how to create intelligent agents that show emotions to other agents that communicate with them in the same environment.

**Introduction:**

**AI is advancing rapidly at emotional intelligence**

While us humans continue to struggle to understand each other, emotionally intelligent AI has advanced rapidly.

Cameras in phones are ubiquitous and omnipresent, and face-tracking software is already advanced enough to analyze the smallest details of our facial expressions. The most advanced ones can even tell apart faked emotions from real ones.

In addition, voice recognition and natural language processing algorithms are getting better at figuring out our sentiment and emotional state from the audio.

The technologies to analyze emotional responses from faces and voice are already way beyond the skills of an average human, and in many areas exceed the abilities of even the most skilled humans.

Artificial Intelligence can look at our faces to recognize such private qualities as your  [political leaning or IQ](https://www.theguardian.com/technology/2017/sep/12/artificial-intelligence-face-recognition-michal-kosinski).

While AI can decipher almost any emotion from your face or speech, we haven’t yet put a lot of effort in [scientific study of emotionally intelligent AIs](https://venturebeat.com/2017/10/06/ai-innovations-have-an-inevitable-effect-on-human-emotions/).

The advances in this field are currently almost solely driven by commercial interests and human greed.

Media and entertainment companies need our attention and engagement to make money. Companies like Facebook and YouTube have a large number of engineers working to create ever better ways to addict us to their content.

**Big data gives an edge to emotionally intelligent AIs**

Unlike people, AI can leverage your whole online history, which in most cases is more information than anybody can remember about any of their friends.

Some of the most advanced machine learning algorithms developed at Facebook and Google have already been applied on a treasure trove of data from billions of people.

These algorithms already know what your desires, biases and emotional triggers are, based on your communication, friends and cultural context. In many areas, they understand you better than you know yourself.

The progress of algorithms has gone so far that Facebook and Google are now accused of creating [filter bubbles](https://en.wikipedia.org/wiki/Filter_bubble) that can effect public opinion, rapidly change political landscapes and sway elections.

These algorithms are getting so complex that they are becoming impossible to fully control by humans. Facebook’s chief of security **Alex Stamos** [recently tweeted](https://techcrunch.com/2017/10/07/alex-stamos/) that journalists are unfairly accusing them for manipulation, when in reality there are no solutions available that wouldn’t lead to someone accusing them of bias.

**The future of emotional artificial intelligence**

People have a lot of biases, which cloud our judgment. We see the world as we wish it to be, not as it is. Algorithms today, being made by people, incorporate some hints of our biases too. But if we wanted to remove such biases, it would be relatively easy to do.

As artificial intelligence gets better at manipulating us, I see a future where people happily submit their lives to the algorithms. We can already see it in practice. Just look around yourself in public — almost everyone is glued to the their smartphones.

Today, people touch their phones on average 2,617 times a day.

**System development:**

The OCC Model  
From a practical point of view, the developer of a screen character of robot is wise to  
build upon existing models to avoid reinvent the wheel. Several emotion models are  
available [7, 8]. However, Ortony, Clore and Collins [9] developed a computational  
emotion model, that is often referred to as the OCC model, which has established  
itself as the standard model for emotion synthesis. A large number of studies  
employed the OCC model to generate emotions [2-4, 10, 11]. This model specifies 22  
emotion categories based on valenced reactions to situations constructed either as  
being goal relevant events, as acts of an accountable agent (including itself), or as  
attractive or unattractive objects (see Figure 1). It also offers a structure for the  
variables, such as likelihood of an event or the familiarity of an object, which  
determines the intensity of the emotion types. It contains a sufficient level of  
complexity and detail to cover most situations an emotional interface character might  
have to deal with.  
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Fig. 1. The OCC model of emotions.  
When confronted with the complexity of the OCC model many developers of  
characters believe that this model will be all they ever need to add emotions to their  
character. Only during the development process the missing features of the model and  
the problem of the context become apparent. These missing features and the context  
in which emotions arise are often underestimated and have the potential to turn the  
character into an unconvincing clown. I will point out what the OCC model is able to  
do for an embodied emotional character and what it does not.  
The OCC model is complex and this paper discusses its features in terms of the  
process that characters follow from the initial categorization of an event to the  
resulting behavior of the character. The process can be split into four phases:  
1. Categorization - In the categorization phase the character evaluates an event,  
action or object, resulting in information on what emotional categories are  
affected.  
2. Quantification - In the quantification phase, the character calculates the  
intensities of the affected emotional categories.  
3. Interaction - The classification and quantification define the emotional value  
of a certain event, action or object. This emotional value will interact with  
the current emotional categories of the character.  
4. Mapping - The OCC model distinguishes 22 emotional categories. These  
need to be mapped to a possibly lower number of different emotional  
expressions.  
Categorization  
In the categorization phase an event, action or object is evaluated by the character,  
which results in information on what emotional categories are affected. This  
categorization requires the character to know the relation of a particular object, for  
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example, to its attitudes. Depending on this evaluation either the “love” or “hate”  
emotional category will be affected by the object.  
Consider this example: a character likes bananas and the user gives him a whole  
bunch. The character will evaluate the consequences of the event for the user, which  
results in pity, since the user has a whole bunch of bananas less. It will also evaluate  
the consequences of the event for itself, which results in satisfaction because it  
received a bunch of bananas. Next, it evaluates the action of the user, which results in  
admiration and finally the aspect of the object, which results in love. It appears that  
ironic that the category “love” is being used in the OCC model only for objects, since  
the more important usage for this word is certainly found in human-human  
relationships.  
To do this classification the character needs an extensive amount of knowledge.  
First, it needs to know its relationship to the user, which was assumed to be good.  
Hence, pity is triggered and not resentment. Moreover, it needs to know what this  
event means to the user. Otherwise the character’s happy-for category might be  
triggered (User Model). Second, it needs to have a goal “staying alive” to which the  
bananas contribute (Goals). Third, it needs to know what to expect from the user.  
Only knowing that the user does not have to hand out bananas every other minute the  
character will feel admiration (Standards). Last, it needs to know that it likes bananas  
(Attitudes).  
The standards, goals and attitudes of the character that the OCC model requires need  
to be specified, organized and stored by the designer of the character. A new  
character knows even less than a newborn baby. It does not even have basic instincts.  
One way to store this knowledge could be an exhaustive table in which all possible  
events, actions and objects that the character might encounter are listed together with  
information on which emotional categories they affect and how their intensity may be  
calculated. This approach is well suited for characters that act in a limited world.  
However, it would be rather difficult, for example, to create such an exhaustive list  
for all the events, actions and objects that the character might encounter at the home  
of the user. With an increasing number of events, actions and objects, it becomes  
necessary to define abstractions. The bananas could be abstracted to food, to which  
also bread and coconuts belong. The categorization for the event of receiving food  
will be the same for all types of food. Only their intensity might be different, since a  
certain food could be more nutritious or tasty. However, even this approach is  
inherently limited. The world is highly complex and this approach can only function  
in very limited “cube” worlds.  
This world model is not only necessary for the emotion model, but also for other  
components of the character. If, for example, the character uses the popular Belief,  
Desires and Intention (BDI) architecture [12], then the desires correspond to the goals  
of the emotion model. The structure of the goals is shared knowledge. So are the  
standards and attitudes. The complexity of the OCC model has a direct influence on  
the size of the required world model. However, the AI community has long given up  
the hope to be able to create extensive world models, such as the widely known Cyc  
database. The amount of information and its organization appears overwhelming.  
Only within the tight constraints of limited worlds was it possible so far to create  
operational world models.  
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As mentioned above, the OCC model distinguishes 22 emotional categories (see  
Figure 1). This rather cumbersome and to some degree arbitrary model appears to be  
too complex for the development of believable characters [13]. The OCC model was  
created to model human emotions. However, it is not necessary to model a precise  
human emotion system to develop a believable character. A “Black Box” approach  
[14] appears to be sufficient. The purpose of this approach is to produce outcomes or  
decisions that are similar to those resulting from humans, disregarding both the  
processes whereby these outcomes are attained as well as the structures involved.  
Such a “Black Box” approach is more suitable, particularly since the sensory, motoric  
and cognitive abilities of artificial characters are still far behind the ones of humans.  
The characters emotion system should be in balance with its abilities. Several reason  
speak for a simplification of the OCC model.  
First, only those emotional categories of the OCC model should be used that the  
character can actually use. If a character uses the emotional model only to change its  
facial expression then its emotion categories should be limited to the ones it can  
express. Elliot [2] implemented all 22 emotional categories in his agents because they  
were able to communicate each and every one to each other. This is of course only  
possible for character-character interaction in a virtual world. It would be impossible  
for characters that interact with humans, since characters are not able to express 22  
different emotional categories on their face. Ekman, Friesen and Ellsworth [15]  
proposed six basic emotions that can be communicated efficiently and across cultures  
through facial expressions.  
Second, some emotional categories of the OCC model appear to be very closely  
related to others, such as gratitude and gratification, even thought the conditions that  
trigger them are different. Gratification results from a praiseworthy action the  
character did itself and gratitude from an action another character did. It is not clear if  
such a fine grained distinction has any practical advantages for the believability of  
characters.  
Last, if the character does not have a user model then it will by definition not be  
able to evaluate the consequences of an event for the user. In this case, the “fortunes  
of others” emotional categories would need to be excluded. Ortony acknowledged  
that the OCC model might be too complex for the development of believable  
characters [13]. He proposed to use five positive categories (joy, hope, relief, pride,  
gratitude and love) and five negative categories (distress, fear, disappointment  
remorse, anger and hate). Interestingly, he excluded the emotional categories that  
require a user model. These ten emotional categories might still be too much for a  
character that only uses facial expressions. Several studies simplified the emotional  
model even further to allow a one-to-one mapping of the emotion model to the  
expressions of the character [3, 16].  
Quantification  
The intensity of an emotional category is defined separately for events, actions and  
objects. The intensity of the emotional categories resulting from an event is defined as  
the desirability and for actions and objects praiseworthiness and appealingness  
respectively (see Figure 1). One of the variables that is necessary to calculate  
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desirability is the hierarchy of the character’s goals. A certain goal, such as  
downloading a certain music album from the internet, would have several sub goals,  
such as download a specific song of that album. The completed goal of downloading  
of a whole album will evoke a higher desirability than the completed goal of  
downloading of a certain song, because it is positioned higher in the hierarchy.  
However, events might also happen outside of the character’s current goal structure.  
The character needs to be able to evaluate such events as well. Besides the goal  
hierarchy, the emotion model also needs to keep a history of events, actions and  
objects. If the user, for example, gives the character one banana after the other in a  
short interval then the desirability of each of these events must decrease over time.  
The character needs to be less and less enthusiastic about each new banana. This  
history function is not described in the original OCC model, but plays an important  
role for the believability of the character. The history function has another important  
advantage. According to the OCC model, the likelihood of an event needs to be  
considered to calculate its desirability. The history function can help calculating this  
likelihood. Lets use the banana example again: The first time the character receives a  
banana, it will use its default likelihood to calculate the desirability of the event.  
When the character receives the next banana, it will look at the history and calculate  
how often it received a banana in the last moments. The more often it received a  
banana in the past the higher is the likelihood of this event and hence the lower is its  
desirability. After a certain period of not receiving any bananas the likelihood will fall  
back to its original default value. This value should not be decreased below its default  
value, because otherwise the character might experience an overdose of desirability  
the next time it receives a banana. Another benefit of the history function is the  
possibility to monitor the progress the character makes trying to achieve a certain  
goal. According to the OCC model, the effort and realization of an event needs to be  
considered to calculate its desirability. The history function can keep track of what the  
character has done and hence be the base for the calculation of effort and realization.  
Mapping  
If the emotion model has more categories than the character has abilities to express  
them, the emotional categories need to be mapped to the available expressions. If the  
character, for example, uses only facial expression then it may focus on the six basic  
emotions of happiness, sadness, anger, disgust, fear and surprise [15]. Interestingly,  
there is only one positive facial expression to which all 11 positive OCC categories  
need to be mapped to: the smile. Ekman [17] identified several different types of  
smiles but their mapping to the positive OCC categories remains unclear. The 11  
negative OCC categories need to be mapped to four negative expressions: Anger,  
Sadness, Disgust and Fear. The facial expression of surprise cannot be linked to any  
OCC categories, since surprise is not considered to be an emotion in the OCC model.  
Even though the character might only be able to show six emotional expressions on  
its face, the user might very well be able to distinguish between the expression of love  
and pride with the help of context information. Each expression appears in a certain  
context that provides further information to the viewer. The user might interpret the  
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smile of a mother next to her son receiving an academic degree as pride, but exactly  
the same smile towards her husband as love.  
Reflection  
The main limitation of the OCC model is its reliance on world model. Such models  
have only been successfully used in very limited worlds, such as pure virtual worlds  
in which only virtual characters operate. Furthermore, the OCC model will most  
likely only be one part of a larger system architecture that controls the character or  
robot. The emotional states of the OCC model must interact with the other states. Not  
only the face of the character is influenced by the emotional state of the character, but  
also its actions. It would be unbelievable if the character showed an angry expression  
on its face, but acted cooperatively. The mapping of the emotional state should be  
based on strong theoretical foundations. Such theoretical foundations might not be  
available for every action that a character might be able to execute and thus force the  
developer of the character to invent these mappings. This procedure has the intrinsic  
disadvantage that the developer might introduce an uncontrolled bias based on his or  
her own experiences and opinions.  
Besides the actions of the character, the emotional state may also influence the  
attention and evaluation of events, actions and objects. In stress situations, for  
example, humans tend to focus their attention on the problem up to the point of  
“tunnel vision”. [13] categorized the behavioral changes of the character through its  
emotional state in self-regulation (such as calming down), other-modulation (punish  
the other to feel better) and problem solving (try to avoid repetition). The latter will  
require the history function mentioned above. The emotional state of the character  
might even create new goals, such as calming down, which would result in actions  
like meditation. Facial Expression Synthesis  
There is a long tradition within the Human-Computer Interaction (HCI) community of  
investigating and building screen based characters that communicate with users [18].  
Recently, robots have also been introduced to communicate with the users and this  
area has progressed sufficiently that some review articles are available [19, 20]. The  
main advantage that robots have over screen based agents is that they are able to  
directly manipulate the world. They not only converse with users, but also perform  
embodied physical actions.  
Nevertheless, screen based characters and robots share an overlap in motivations  
for and problems with communicating with users. Bartneck et al. [21] has shown, for  
example, that there is no significant difference in the users’ perception of emotions as  
expressed by a robot or a screen based character. The main motivation for using facial  
expressions to communicate with a user is that it is, in fact, impossible not to  
communicate. If the face of a character or robot remains inert, it communicates  
indifference. To put it another way, since humans are trained to recognize and  
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interpret facial expressions it would be wasteful to ignore this rich communication  
channel.  
Compared to the state of the art in screen-based characters, such as Embodied  
Conversational Agents [18], however, the field of robot’s facial expressions is  
underdeveloped. Much attention has been paid to robot motor skills, such as  
locomotion and gesturing, but relatively little work has been done on their facial  
expression. Two main approaches can be observed in the field of robotics and screen  
based characters. In one camp are researchers and engineers who work on the  
generation of highly realistic faces. A recent example of a highly realistic robot is the  
Geminoid H1, which has 13 degrees of freedom (DOF) in its face alone. The annual  
Miss Digital award [22] may be thought of as a benchmark for the development of  
this kind of realistic computer generated face. While significant progress has been  
made in these areas, I have not yet reached human-like detail and realism, and this is  
acutely true for the animation of facial expressions. Hence, many highly realistic  
robots and character currently struggle with the phenomena of the “Uncanny Valley”  
[23], with users experiencing these artificial beings to be spooky or unnerving. Even  
the Repliee Q1Expo is only able to convince humans of the naturalness of its  
expressions for at best a few seconds [24]. In summary, natural robotic expressions  
remain in their infancy [20].  
Major obstacles to the development of realistic robots lie with the actuators and the  
skin. At least 25 muscles are involved in the expression in the human face. These  
muscles are flexible, small and can be activated very quickly. Electric motors emit  
noise while pneumatic actuators are difficult to control. These problems often result in  
robotic heads that either have a small number of actuators or a somewhat larger-thannormal head. The Geminoid H1 robot, for example, is approximately five percent  
larger than its human counterpart. It also remains difficult to attach skin, which is  
often made of latex, to the head. This results in unnatural and non-human looking  
wrinkles and folds in the face.  
At the other end of the spectrum, there are many researchers who are developing  
more iconic faces. Bartneck [25] showed that a robot with only two DOF in the face  
can produce a considerable repertoire of emotional expressions that make the  
interaction with the robot more enjoyable. Many popular robots, such as Asimo, Aibo  
and PaPeRo have only a schematic face with few or no actuators. Some of these only  
feature LEDs for creating facial expressions. The recently developed iCat robot is a  
good example of an iconic robot that has a simple physically-animated face. The  
eyebrows and lips of this robot move and this allows synthesis of a wide range of  
expressions.  
Another important issue that needs to be considered when designing the facial  
expression of the character is that they need to be convincing and distinct at low  
intensity levels. Most events that a character encounters will not trigger an ecstatic  
state of happiness. The evaluation of a certain event should be roughly the same as  
could be expected of a human and most events that humans encounter in everyday life  
do unfortunately not result in ecstasy. If the character managed to download a  
complete album of music it still did not save the world from global warming. Hence,  
it should only show an appropriate level of happiness.  
While there is progress in the facial expressions of robot faces, we are sill facing  
several conceptional problems that stem from the field of Artificial Intelligence. Lets  
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take the example of emotions that I discussed in detailed above. The emotional state  
of the character is defined through values for each of its emotional categories. This  
emotional state needs to be expressed through all available channels. A conversational  
embodied character, for example, needs to express its emotional state through its  
speech and facial expressions. It would be unconvincing if the character would smile,  
but speak with a monotonous voice. However, the systematic manipulation of speech  
to express emotions remains a challenge for the research community. Emotional facial  
expressions are understood better, but a fundamental questions remains. Shall the  
character only express the most dominant emotional category, or shall it express every  
category at the same time and hence show a blend of emotions. The blending of  
emotional expression requires a sophisticated face, such as Baldi from the CSLU  
Toolkit. Cartoon like characters, such as eMuu [16] or Koda’s Poker Playing Agent  
[3] are not able to show blends and therefore they can only express the most dominant  
emotional category.  
Fig. 2. Robots with animated faces  
It becomes obvious that the problems inherited by human-robot interaction (HRI)  
researchers from the field of AI can be severe. Even if we neglect philosophical  
aspects of the AI problem and are satisfied with a computer that passes the Turing  
test, independently of how it achieves this, we will still encounter many practical  
problems. This leads us to the so-called “weak AI” position, namely claims of  
achieving human cognitive abilities are abandoned. Instead, this approach focuses on  
specific problem solving or reasoning tasks.  
There has certainly been progress in weak AI, but this has not yet matured  
sufficiently to support artificial entities. Indeed, at present, developers of artificial  
entities must to resort to scripting behaviors. Clearly, the scripting approach has its  
limits and even the most advanced common sense database, Cyc, is largely  
incomplete. Emotion modeling should therefore not bet on the arrival of strong AI  
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solutions, but focus on what weak AI solutions can offer today. Of course there is still  
hope that eventually also strong AI applications will become possible, but this may  
take a long time.  
When we look at what types of HRI solutions are currently being built, we see that  
a large number of them do barely have any facial features at all. Qrio, Asimo and  
Hoap-2, for example, are only able to turn their heads with 2 degrees of freedom  
(DOF). Other robots, such as Aibo, are able to move their head, but have only LEDs  
to express their inner states in an abstract way. While these robots are intended to  
interact with humans, they certainly avoid facial expression synthesis. When we look  
at robots that have truly animated faces, we can distinguish between two dimensions:  
DOF and iconic/realistic appearance (see Figure 2).  
Robots in the High DOF/Realistic quadrant not only have to fight with the  
uncannieness [26, 27] they also may raise user expectations of a strong AI which they  
are not able to fulfill. By contrast, the low DOF/Iconic quadrant includes robots that  
are extremely simple and perform well in their limited application domain. These  
robots lie well within the domain of the soluble. The most interesting quadrant is the  
High DOF/Iconic quadrant. These robots have rich facial expressions but avoid  
evoking associations with a strong AI through their iconic appearance. I propose that  
research on such robots has the greatest potential for significant advances in the use of  
emotions in HRI. Conclusion  
A problem that all these artificial entities have to deal with is, that while their  
expression processing has reached an almost sufficient maturity, their intelligence has  
not. This is especially problematic, since the mere presence of an animated face raises  
the expectation levels of its user. An entity that is able to express emotions is also  
expected to recognize and understand them. The same holds true for speech. If an  
artificial entity talks then we also expect it to listen and understand. As we all know,  
no artificial entity has yet passed the Turing test or claimed the Loebner Prize. All of  
the examples given in Table 1 presuppose the existence of a strong AI as described by  
John Searle [28].  
The reasons why strong AI has not yet been achieved are manifold and the topic of  
lengthy discussion. Briefly then, there are, from the outset, conceptual problems. John  
Searle [28] pointed out that digital computers alone can never truly understand reality  
because it only manipulates syntactical symbols that do not contain semantics. The  
famous ‘Chinese room’ example points out some conceptual constraints in the  
development of strong AIs. According to his line of arguments, IBM’s chess playing  
computer “Deep Blue” does not actually understand chess. It may have beaten  
Kasparov, but it does so only by manipulating meaningless symbols. The creator of  
Deep Blue, Drew McDermott [29], replied to this criticism: "Saying Deep Blue  
doesn't really think about chess is like saying an airplane doesn't really fly because it  
doesn't flap its wings." This debate reflects different philosophical viewpoints on what  
it means to think and understand. For centuries philosophers have thought about such  
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questions and perhaps the most important conclusion is that there is no conclusion at  
this point in time. Similarly, the possibility of developing a strong AI remains an open  
question. All the same, it must be admitted that some kind of progress has been made.  
In the past, a chess-playing machine would have been regarded as intelligent. But now  
it is regarded as the feat of a calculating machine – our criteria for what constitutes an  
intelligent machine has shifted.  
In any case, suffice it to say that no sufficiently intelligent machine has yet  
emerged that would provide a foundation for many of the advanced application  
scenarios that have been imagined for emotional agents and robots. The point I hope  
to have made with the digression into AI is that the application dreams of researchers  
sometimes conceal rather unrealistic assumptions about what is possible to achieve  
with current technology. Emotion models heavily rely on the progress made in  
artificial intelligence and hence I would like to reply to Minsky’s statement with a  
question: “Will emotional machines have intelligence?”

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