The Illusion of Robotic Life

Principles and Practices of Animation for Robots

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ABSTRACT

This paper describes our approach on the development of the expression of emotions on a robot with constrained facial expressions. We adapted principles and practices of animation from Disney^{TM}and other animators for robots, and applied them on the development of emotional expressions for the EMYS robot. Our work shows that applying animation principles to robots is beneficial for human understanding of the robots' emotions.

Categories and Subject Descriptors

I.2.9 [**Artificial Intelligence**]: Robotics; H.5.1 [**Multimedia Information Systems**]: Animations, Evaluation/methodology; J.4 [**Social and Behavioral Sciences**]: Psychology; J.5 [**Arts and Humanities**]: Arts, fine and performing

General Terms

Design, Affective Computing

Keywords

Animation, Facial Expressions, Emotions

1. INTRODUCTION

Nearly one hundred years ago, the world witnessed the birth of animation movies, which has clearly marked the culture and art of the past century. Today technology has evolved, bringing us closer to having such animated features present in our real life. We are talking, of course, of animated robots. Robot use is scaling from the industrial production factories into our homes and into our lives, rising as a trend of becoming our own artificial companions and friends in the future[1]. One important aspect that has been gaining focus on social robots is non-verbal communication. This kind of affective behaviour plays an important role on the establishment and maintenance of long-term relationships, which is one of the goals for social robots [7]. Breazeal also showed that it is important for the user to understand the robot's behaviour, in order to maintain a social relationship [10]. Non-verbal communication can be achieved through several channels [6]. Our current work, however, focuses on the expression of emotions solely through animation [9, 8, 47, 2, 40, 19, 44]. We are especially interested in understanding how to develop a method of expressing emotions through animation in robots with constrained appearance and expression [10]. Van Breemen defines animation of robots as *the process of computing how the robot should act such that it is believable and interactive* [47]. We show that applying principles and practices of animation to robots portrays them with a higher degree of understandability when expressing their emotions.

We start by exploring the background that is necessary for our work, and by analysing related work from other authors. We then present our approach, and its two-phase development, with results for each. Finally we draw conclusions and outline our next steps.

[1]LIving with Robots and intEractive Companions, `www.lirec.eu`

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2. BACKGROUND

We seem to know when to 'tap the heart'. Others have hit the intellect. We can hit them in an emotional way.

Walt Disney

Animation artists have struggled for creating believable emotional characters for many years now, and somehow have succeeded [5]. Several different emotional models have also been developed in the field of psychology and adapted for computation, so we must understand how these models can relate to and influence the expression of emotions.

2.1 Animation Principles and Practices

One approach for animating robots is making use of animation principles and practices. Most professional animators follow a set of twelve principles that result of more than 60 years of Disney^{TM}productions. These were compiled in a book by Johnston and Thomas [46], the last two of the Nine Old Men[2], thus representing the bible of animation. Other animators have explored different perspectives than Disney^{TM}'s, such as Bob Clampett, Chuck

[2]A group of nine animators that worked closely with Walt Disney since the debut feature Snow White and the Seven Dwarfs (1937) and onto The Fox and The Hound (1981).

Jones and Tex Avery, with Warner Bros.™, who explored a deeper connection between emotion, exaggeration and character expressiveness. They have credit on short films featuring Bugs Bunny, Daffy Duck, Will E. Coyote, Porky Pig[3] and so on. William Hanna and Joseph Barbera are also mentioned as strong references from the Metro-Goldwyn-Mayer™Company, however, their focus was more story-driven than that of the Warner Bros.™productions, as we can find in the Scooby Doo and Tom & Jerry series[4]. Their animation is generally regarded as more simplistic, however still expressive as of the others [28]. Jim Henson's television puppet phow can also be viewed as interesting reference and inspiration for the animation of robots, because they deal with animating real physical characters that in most cases do not have much freedom of expressiveness [17].

2.1.1 Disney™'s Twelve Principles of Animation applied to Robots

Van Breemen [47] has already proposed to apply the Principles of Animation to robots, claiming *user-interface robots to have the same problem of early day's animations: they miss the illusion of life.* The Twelve Principles of Animation, described by Johnston and Thomas [46], should impact the creation of robot animated expressions. We present each principle below while relating them to robot animation.

Squash and Stretch
The movement and liquidness of an object reflects that the object is alive. One rule of thumb is that despite them changing their form, the objects should keep the same volume while squashing and stretching. This principle is hard to apply to robots, because robots are generally composed of rigid parts.

Anticipation
Anticipating movements and actions helps viewers and users to understand what a character is going to do. That anticipation helps the user to interpret the character or robot in a more natural and pleasing way.

Staging
Staging is related to the general set-up in which the character expresses itself. This principle is related to making sure that the expressive intention is clear to the viewer. Some ways of accomplishing this are by positioning lights, camera, music, characters and surrounding objects. In robots this suggests that we can use multi-modal expression with lights or sound.

Straight Ahead and Pose-to-Pose
Straight ahead action is more of a free method, when the animator knows what he wants to do, but hasn't completely foreseen it, so he starts on the first frame and goes on sequentially animating on to the last. Pose-to-Pose animation is used when the sequence is pre-planned, and is especially useful when making use of physics and synchronizing movements. We can regard this as having a robot to produce interactive, procedural animation (straight-ahead), or pre-designed animation, which can be synced and blended with other kinds of behaviours (Pose-to-Pose).

[3]These characters are ™of, and ©Warner Bros. Entertainment Inc.

[4]Scooby-Doo and Tom & Jerry are ™of, and ©Hanna-Barbera.

Follow-Through and Overlapping Action
This principle works as an opposite of Anticipation. When a character stops doing something, it shouldn't stop abruptly, for that causes an unnatural feeling. This follow-through animation is generally associated with inertia, but can also be used to emphasize the stop. A character that punches another one will first pull its body and arm back (anticipation), then punch (action), and slightly fall forward while trying to regain balance, give step or two or even fall down (follow-through/reaction). These principles have impact both on causing the impression that the robot is part of our natural world, and also to mark that an action has ended.

Slow In and Slow Out
This principle helps the motion of objects and characters to seem natural and pleasant to the viewers. Along with anticipation and follow-through, objects shouldn't be abrupt when they start or stop moving. A hand pulling back for a punch accelerates backwards, decelerates to a stop, and then accelerates forward to the punch. When a character smiles, its mouth doesn't suddenly turn to a smile, it slowly blends into it. In robot animation this principle is one of the major ones to apply, as it states that animations should softly blend one into another, or in and out of the character. Van Breemen [48] called this Merging Logic when he applied it in Philips's iCat[5] .

Arcs
This principle states that natural motions occur in arcs, so that should be taken into account when designing animation. When a person looks to the left and the right, it shouldn't just perform a horizontal movement, but also some vertical movement, so that the head will be pointing slightly upwards or downwards than it was while facing straight ahead. For robots this principle can be used both for pre-designed animations, and also for procedural ones.

Secondary Action
This kind of action does not directly contribute to the expression of the character, but aids in making it believable. When people speak to each other, they often scratch some part of their body, adjust their hair, or even look away from the person with who they are interacting. These actions are designated as secondary actions. One simple case of applying this to robots can be adding random blinks to the eyes, and adding a soft, slow sinusoidal motion to the body to simulate breathing (lat. *anima*).

Timing
Animation is, of course, all about timing, so it seems redundant to include timing as a principle. However, there is another purpose here. First, timing can help us to understand a motion to belong to a particular physical world. Timing of physical motion on Earth or on the Moon is very different. But timing can also be used as expression. A fast motion often suggests that a character is active and engaged on what it's doing. Saerbeck and Bartneck [40] have even recently

[5]©2004-2012 Koninklijke Philips Electronics N.V.

correlated acceleration of a movement with the perceived arousal of a robot. For robots the scalability factor of time is interesting to explore, as the same movement, pre-animated or procedural, can have different meanings depending on the timing used, which aids on reusing motions and animations with different emotions.

Exaggeration
This principle, along with Timing, is one of they key magic features in animation. Animated characters and objects do not need to follow the rules of our world and our physics. Exaggeration can be used to emphasize the robot's movements, expressions or actions, in order to make them more noticeable and convincing.

Solid Drawing
This is another principle that seems not to relate to robot animation, despite being able to be related to robot design. However, this principle also states some rules to follow while designing poses. A character should not stand stiff and still. We generally put more of our weight on only one of the legs, and often to not keep our hands at the same level. The main concept to get from this principle is asymmetry. Faces rarely exhibit the same expression on the left and right sides, and almost no poses are symmetrical, unless one wants to convey the feeling of stiffness.

Appeal
It is obvious that most people prefer beautiful, appealing characters than grotesque and ugly ones. However, this principle does not relate to "drawing pretty things", but to the fact that the viewers appeal should be taken into account when drawing and animating characters. If we want a viewer or user to love a character, then it should be beautiful and gentle. If we want them to hate a character it should be stiff and grotesque. Even if one wants to make viewers and users feel pity for a character (such as an anti-hero), then the character's motion and behaviour should generate that feeling, through clumsy and embarrassing behaviours. Motion and behaviours of robots should also be easy to understand, because if the users don't understand what they see, their appeal for the robot will fall.

2.1.2 Warner Bros™. and MGM™

The works by Warner Bros™. and MGM™pay special focus on one special principle that is Exaggeration.
Disney™'s principles already include this one, however, these other animators took this concept much further. Their exaggeration was especially physical, and generally included extreme distortions and breaking up a character or object in order to express emotions and key moments. Tex Avery was one of the greatest animators of all time, and created lots of concepts and gags that have remained not just as animation *clichés*, but also as expressive guidelines [11]. He was especially a master in exaggeration, being credited as the creator of the eyes-popping-out expression that is now sometimes called *the Tex Avery expression*, or just *a Tex Avery*. The practice of these artists is not as well documented as that of Disney™'s. However, while viewing their work one can understand not only a common line underneath them, which helps to define it as a style different than Disney™'s, but also notice that animation can do a lot more than what Disney™principles state.

2.1.3 Puppet Animation

If we are looking at artistic influences for animating robots, we must take a look at a genre that actually shares some resemblance with it. Puppet animation follows some of the guidelines that traditional animation follows. However, in practice, things work out very differently. Puppets are physical objects that are built in order to move and be expressive, and are subject to the laws of physics and our real world. If we replace the word *Puppets* with *Social Robots* in this last sentence, it would still be valid. Jim Henson created a puppet television show which has influenced several generations [17]. Their puppets are characterized by being very simple, and by not possessing many moving parts to be used in expression. Thus, animators had to develop their own non-verbal language suited for their puppets. One example is their puppet's head, which is generally characterized by an egg-like shape that is sliced somewhere in order to just open and close as a mouth. This mouth is frequently the only moving part of their head; even their eyes cannot gaze or shut. If we watch episodes of the series, we will find moments in which the characters cover their eyes with their hands in order to "close their eyes".
It is empirically clear that exhibiting emotions solely through facial expression is nearly impossible with a mouth that just opens and closes; we recall here that a simple smile is expressed especially with the corners of the mouth, and lower eyelids. So they generally associate whole body movement to the mouth in order to express emotions. For fear, one may find that the mouth trembles open, the hands grab the face, and the body assumes a posture of withdrawal. For happiness the mouth will open wide and the whole puppet will bounce around sort of crazy with its arms balancing freely to the movement. An angry expression is achieved by tilting the puppet (especially the head) against its object or character of hate, closing its mouth and pulling back its arms. As in most artistic inspirations, the best way to learn their principles and practices is by watching the episodes and eventually tag them with emotions and expressions, so that they may serve of reference.

2.2 Emotion Models

Before trying to express emotions with robots, it is important to analyse how emotions are being computed. We will not focus here on understanding which model or classification is better. Instead, we look to understand what kind of computational models might be used to trigger the expression of emotions, so that we can take into account than information.
One of the most referenced emotional models is FACS by Ekman and Friesen [16]. They establish that through facial expression, humans can universally recognize in other humans six basic emotions: anger, disgust, fear, joy, sadness and surprise. Albeit simple and universal, this set of emotions is somewhat limited, as humans can actually express and recognize much more. Another popular theory of emotions is that of Ortony, Clore and Collins [36], generally referred to as the OCC model, which defines 22 different emotional categories. However, this model is complex, and it isn't simple to understand how one can express each of those 22 emotions. Bartneck [3] has developed a model that

makes use of the OCC theory, and states that emotion processing is a five-phase process:
Classification What do I feel about what just happened?
Quantification How much do I feel about it?
Interaction How does this affect what I was already feeling?
Mapping What should I do to express this feeling?
Expression How should I do that?
For our work we are mostly interested in the Mapping and the Expression phases, however, it is important to understand what lies beneath them. Bartneck also suggests that the OCC emotions may somehow be mapped to the Ekman's expressions, but this mapping is not trivial. There are 11 positive emotional categories in the OCC model, but only one positive Ekman expression (smile). A workaround for this can be to contemplate the Interaction phase information for expression, so that, if possible, we can perform blending of expressions. Another popular model for emotions is the Pleasure-Arousal-Dominance (PAD), proposed by Mehrabian [31]. This is a three-dimensional model used to define an emotion in terms of three dimensions: Pleasure, Arousal and Dominance. This approach is scientific and adequate for computation, as emotions form a continuous space characterized by those three variables. One advantage of this model is that the transition from one emotion to another may be seamless, however, when transitioning from emotion A to emotion B, the transition may go through an emotion C, which can be invalid.

3. RELATED WORK

Several other authors have looked into developing a framework for expressive behaviour. Some have focused on describing languages for specification of hand and arm gestures, and on expressive dialogue acts [18, 12, 26, 25, 38, 13]. Badler [1] has presented an Expressive MOTion Engine (EMOTE) that implements LMA [21] using high-level parameters for human animation control; however, this solution is designed for anthropomorphic characters. Currently, the SAIBA framework [24] is becoming popular, but authors have used it mainly oriented at humanoid characters or robots [49, 34].

As to studying the expression of emotions with robots, various authors have done their own studies, and have therefore drawn conclusions on their specific robot [43, 44, 41, 10, 45, 52, 27, 19, 48, 23]. [51] have developed a robot that mimics human expressions by observation. Their robot recognizes expressions from videos, and maps the expressions' FACS features into the robot's own effectors.

Bethel [6] has strived into studying how to express emotions in robots that do not possess expressive capabilities. Her work focuses on robots that are mean to be functional, like search-and-rescue or military robots, and how to use multi-modal expression for the correct communication of the robot's emotional state and empathic behaviour. Multi-modal expression of emotions with robots was also explored by Jung et al. [22] and Gorostiza et al. [19].

A mark on our research is the fact that we have found that most works [10, 15, 24, 34, 32] have integrated interaction with expression, and therefore have developed expressive behaviour for their specific interactive scenarios. We aim at studying how the definition of expressive behaviour may be dissociated from that interaction, while remaining useful for the interaction to trigger and produce such behaviour.

The need for an exhaustive and general comprehension on analysis, modelling and synthesis of facial expression in robots has been reported by Bartneck and Lyons [4]. Schröder et al. have proposed a general mark-up language that is not dependant of any emotion model or theory, thus marking a possible step for an abstract and broad specification of emotive behaviour [42]. However, their language provides only a structure to gather the description of an emotional expression, with no means on how to accomplish it. Moussa et al. have embarked on one approach for this, using MPEG-4 Facial Animation Parameters (FAP) [37] applied to a humanoid robotic face [33]. However, FAPs are designed for human faces and thus comprehend an extensive number of expressive features for the human face. Saerbeck and Bartneck have also attempted to correlate robotic motion with perceived emotions [40], and concluded that there exists a correlation between a robot's acceleration, and the perceived arousal.

3.1 Designing Emotion for Robots

Recently some authors have looked into design and communication concepts and practices so that they may be incorporated in the engineering of emotional expression. Hess [20] states that *the ability to well communicate emotions is relevant for both the encoder, who would like to be understood, and the decoder, who strives to understand*. Product design is an example of a field that has struggled between creating art/emotion and functional objects [35]. Regarding the design of believable social robots, Dautenhahn [14] divided the design process in two dimensions: the Universal dimension, in which the universal features of a behaviour or expression are abstracted; and the Abstract dimension, in which the designer of the behaviour or expression is free to be creative and develop a more artistically based result. Meerbeek et al. also follow the Universal vs. Abstract dimensions of design, stating that *since human expressions cannot be mapped one-to-one with expressions of the robot, we abstracted the human expressions first* [30]. The same authors have defended that the design of behaviour and expressions of robots should be a blend between an artistic approach and an iterative cycle to evaluate and refine the result, which follows the usual practice both in engineering and usability design. They also consider that using virtual 3D models for animating and visualizing the expressions of a robot is useful, especially if the virtual model is designed with resemblance to the real physical model and its behaviour [29]. [40] conclude that the perceived affective state of a robot is independent of the embodiment, suggesting that we can use motion design tools across different embodiments.

4. EXPRESSING EMOTIONS IN EMYS

Our EMYS robot has eleven degrees of freedom (Figure 1). The head can turn to the sides for panning and gazing, however, the eyes cannot look the other way for gazing or expression. One can notice that EMYS does not have any lower eyelids, which caused some difficulty in some of the expressions. Moreover, the only movement for the mouth (the Lower Plate), is to open and close. This and the lower eyelid absence made it difficult to empirically create a happy expression for Joy, because a smile comes especially from the

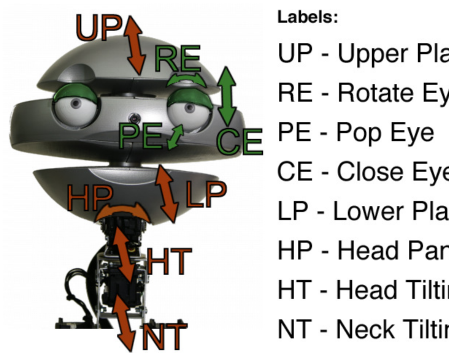

Figure 1: EMYS's facial expression features.

corners of the lips, and the lower eyelids, both of which are absent on EMYS's face. As to asymmetry, the only thing that we can do besides turning the whole face to one side, is closing the eyes and rotating the eyelids. The Upper Plate acts as middle eyebrows, by raising and lowering. Rotation of the eyelids is mostly used as lowering and raising of the outer eyebrows. Our approach for expressing emotions with the EMYS robot was inspired by the work and proposals of van Breemen [47, 48], Dautenhahn [14], Meerbeck et al. [30, 29] and Moussa et al. [33]. We started by creating a virtual interface for our robot using Autodesk 3ds max. The virtual model is the exact model used for the manufacturing of EMYS. Every time the virtual model is updated, a script communicates with the physical robot so that the latter is also updated and synchronized with the virtual one. All the degrees of freedom of the virtual model are also limited in order to provide the same freedom of the physical robot. This setup enabled us to use all the tools available for animation in 3ds max, thus providing us with nearly the same technological freedom as professional 3D animators. Another script provides us with export functionality, so that the animations created in 3ds max may be used by our own external .NET library, so that in the future we may use these animations in any other application that supports loading such type of library. We started to create expressions for EMYS in an iterative cycle, following [30, 29]. The first phase resulted in our initial expressions, which were then refined in the second phase.

5. PHASE 1: INITIAL EXPRESSIONS

For our initial expressions we analysed the work of Ekman and Friesen [16], thus deciding to create expressions for the six basic emotions that they claim to be universally recognized. They define these expressions in terms of FACS, which are features presents in the human face that can be used for expressing and recognizing emotions. MPEG-4 defines FAPs, another model of features that was especially defined for facial expression in virtual characters [37]. However, following [30], we abstracted the FACS and FAPs features into a simpler set, composed of only 9 valenced features that could more easily be mapped to a robotic face. Our approach here was therefore a more simplistic and cartoon-oriented version of [51]'s approach. We considered each feature to have 5 positive values, one neutral and other 5 negative values. For example, one feature is JA (Jaw), for which negative values means Jaw closed, neutral value means jaw relaxed, and positive values mean jaw open. Another example is LE, Lower-Eyelids, for which negative values correspond to closed eyelid (eyelid raised) and positive values to open eyelid (eyelid lowered).
From [16]'s descriptions, we defined the expression of each emotion in terms of ranges that could be set for each feature, so that each expression could have 5 different intensities (from 1 to 5, being that 0 would correspond to the default pose). For happiness, for example, an intensity of 1 (lowest) corresponded to having -1 on the Lower Eyelids (slightly closed), 0 on the Jaw (relaxed) and 1 on the Lip Corners (slightly raised). The intensity of 5 (highest) for happiness was defined as -5 for Lower Eyelids (totally pulled up), 5 for Jaw (mouth wide open as if laughing) and 5 for Lip-Corners (totally pulled up). This first part of our definition corresponds to Dautenhahn's Universal Dimension [14].
We created expressions for EMYS first using these definitions and then adding some creativity due to the fact that EMYS does not have, for example, Lower Eyelids, and that it supports Eyes-Popping. This second part corresponds to Dautenhahn's Abstract Dimension [14].
We followed by a preliminary evaluation, described in [39], to test if the human users were able to correctly identify our expressions. The results showed that Anger and Sadness were easily recognized, however Disgust was confused with Anger, and the other three we all confused between them.

6. PHASE 2: REFINED EXPRESSIONS

After the results from the first phase, we understood that due to the constrained appearance of EMYS's face, we needed to move away from a purely FACS approach and focus on some specific aspects. On this second phase we refined the initial expressions based on the application of the principles of animation just presented.

6.1 Development

Applying principles and practices of animation to robots is currently an artistic process. We believe that in the future we will be able to understand how to make these principles intrinsic to animation systems. Therefore we must first explore the ground before we can draw conclusions on how to generalize them, because each robotic embodiment will function and express itself in different ways. Sharing methods and discussing ideas with the scientific community is therefore, the first step we must take. Our method applied and worked specifically on the EMYS robot; However, it may inspire other researchers on how they may apply them on their own robotic embodiments. It also describes our line of thought on this subject, which can also inspire robot designers and creators, so that the design process may in fact consider these principles. Take exaggeration, for example: Instead of designing eyes that open and close normally, the designer may consider to create eyelids that can open wider than usual, or eyelids that can be extremely pressed up and together. Including controllable leds and displays on the robot also helps on staging, even if it does not seem neces-

sary for the robot's functionality. EMYS has eyes that can pop out, providing us with a new feature to explore, even if functionally he doesn't need it. If he didn't physically support it however, we couldn't do it. We follow with the considerations we had on our robot.
For the distinguishing between Anger and Disgust, we made better use of Exaggeration, Timing and Solid Drawing on the latter one. We emphasized the asymmetry on the eyes (one closing more than the other), and increasing the horizontal panning. We also drove the head back into position in a more resistive way, and kept the eyes pressed during more time. To Anger we added some Exaggeration to the clenching of the eyes, by making the eyelids not only close, but tremble while closed. For both Surprise and Happiness we adjusted the Timing and Staging in order to better differentiate both expressions. Surprise was made more instant, and we also modified the eye-popping in order to make it more noticeable. For Happiness in particular, we drew inspiration from Jim Henson's work[17], in which the puppets bounce around when they are happy. Our robot could not bounce around, but could balance its head back and forth. Fear was also furnished with Exaggeration, also inspired by those puppets, by adding tremble to the chin, which really seemed to emphasize the fear factor, and also some Staging by adding a negative nod to the head, like if the character was pleading in despair. Sadness was kept nearly the same, because it already had good results. We also enhanced all of the expressions with respect to the principles of Arcs, Slow In/Slow Out and Follow Through animation.

6.2 Evaluation - Procedure

To test if human users were able to correctly identify our refinements we filmed the robot's expressions in order to run a video-based online survey. Several authors have supported that HRI studies could use videotaped scenarios as opposite to live interaction [2, 50]
Participants were first presented with information about the purpose and guidelines of the procedure. Evaluation consisted in visualizing a set of videos of EMYS performing an animation, and selecting, for each video, the emotion that was thought EMYS was expressing. Each emotion was expressed in three different intensities, totalling 18 videos, for the 6 basic emotions. We tested only intensities 1, 3 and 5 for each expression, so that the evaluation would not be too long. Each intensity of each expression was presented as an individual 4-second video, and the videos were all presented in a random order. Participants could play each video any number of times, and then choose an option from a forced-choice scale, regarding the perceived expression: *Anger*, *Disgust*, *Fear*, *Joy*, *Sadness*, *Surprise* or *Don't Know*. In the end of the survey we also collected some information about the cultural and artistic habits of the participants.

6.3 Evaluation - Participants

Data of 61 participants from 7 different countries was collected, with ages spanning 17 to 55 (mean age 27.3) and 49.2% being male. 42.6% were from Portugal, 18% from Hungary, 9.9% from Germany, United Kingdom and Poland, and the remaining 3.2% from The Netherlands and India. 73.8% of the participants appreciate Animation Movies, 31.1% of them appreciate Character-Driven Video Games and 23% appreciate Comic Books.

6.4 Evaluation - Results

Our new results showed a majority of correct answers for all of the expressions except for intensity 1 of *Disgust*.

Table 1: Results from our evaluation. *Abbreviations: Ang = Anger, Disg = Disgust, Sad = Sadness, Surp = Surprise, DK = Don't Know*

	Ang	Disg	Fear	Joy	Sad	Surp	DK
Anger1	83.6%	4.9%	1.6%		1.6%		8.2%
Anger3	88.5%	3.3%			1.6%		6.6%
Anger5	90.2%				3.3%		6.6%
Disgust1	1.6%	45.9%	1.6%	1.6%		1.6%	47.5%
Disgust3	19.7%	36.1%	1.6%	1.6%	1.6%	4.9%	34.4%
Disgust5	6.6%	55.7%		3.3%		4.9%	29.5%
Fear1		1.6%	72.1%	4.9%		11.5%	9.8%
Fear3	1.6%	4.9%	67.2%		1.6%		24.6%
Fear5	3.3%	4.9%	73.8%	1.6%		1.6%	14.8%
Joy1	4.9%	3.3%	3.3%	62.3%		13.1%	13.1%
Joy3	1.6%		1.6%	50.8%		16.4%	29.5%
Joy5	3.3%		3.3%	59.0%		21.3%	13.1%
Sadness1	1.6%	1.6%	3.3%	6.6%	50.8%	13.1%	23.0%
Sadness3		1.6%			95.1%		3.3%
Sadness5		4.9%			90.2%		4.9%
Surprise1	3.3%	6.6%		16.4%	1.6%	50.8%	21.3%
Surprise3	1.6%		11.5%	1.6%		67.2%	18%
Surprise5		3.3%	13.1%	4.9%		67.2%	11.5%

Table 2: Overall results from our online evaluation.

	None Correct	One Correct	Two Correct	All Correct
Anger	4.9%	3.3%	16.4%	75.4%
	8.2%		91.8%	
Digust	24.6%	31.1%	26.3%	18.0%
	55.7%		44.3%	
Fear	4.9%	19.7%	32.8%	42.6%
	8.2%		91.8%	
Joy	18.0%	21.3%	31.2%	29.5%
	39.3%		60.7%	
Sadness	3.3%	3.3%	47.5%	45.9%
	6.6%		93.4%	
Surprise	8.2%	18.0%	52.5%	21.3%
	26.2%		73.8%	

Table 1 shows the results. For each emotion that we expected to recognize, the table contains three lines, each corresponding to a different intensity for that emotion. The results for all the expressions yielded significant values. The columns contain the percentage of participants that, for each expression, selected each of the emotions displayed in the title of the column. In the first line, for example, *Anger1* shows that for intensity 1 of *Anger*, the majority of the respondents (83.6%) selected *Anger*, while 8.2% selected *Don't Know*, 4.9% selected *Disgust*, and the remaining 3.2% were equally divided between *Fear* and *Sadness*. Lines *Anger3* and *Anger5* correspond to intensities 3 and 5 of *Anger*.

Table 2 shows the overall results for each emotion, with the percentage of people that got all three intensities correct, only two intensities correct, only one of them, or none. For *AngerOverall*, for example, we see that most people (75.4%) selected the correct emotion for all three intensities that were shown, thus supporting that this expression was successfully

designed and expressed. In a summary, we consider that *Anger*, *Fear* and *Sadness* had very good results (over 90% got at least two of the expressions correct). *Anger* and *Sadness* were already expected to have good results, because of the first evaluation, however for *Fear* this was a great improvement. *Surprise* and *Joy* had fairly good results, as more than 60% of the participants identified correctly at least two of the three intensities shown. *Disgust* was our worst result. Intensity 1 of *Disgust* had slightly more participants selecting *Don't Know* (47.5%) than *Disgust* (45.9%). However for intensities 3 and 5, most participants identified the emotion correctly.
Nevertheless, Disgust was the only emotion for which less than 50% got at least two of the expressions correct.

7. CONCLUSIONS AND FUTURE WORK

We have given a step further into the design and development of non-verbal expression of emotions in social robots by making use of animation principles and practices. Our work derives from other authors who have given great contribute to this field of study, by reinforcing that not only psychologists, but also artists - especially animation artists - have an important role in supporting scientists on this quest. Expressing emotions in robots is thus equivalent to creating the illusion of life in robots: making people think and feel that the mechanical being they see in front of them actually has a *persona* and feelings. Our results were positive and support that we continue to develop our studies on this topic. One of the next steps that we plan is to study and integrate multi-modal expression in our model that is inspired both by art and psychology, using colors (through lights) and sound. We also plan on repeating our study on other robots, to try to find out what kind of general principles we can gather and apply in respect to animation and expression of robots.

To give the Coyote a look of anticipatory delight, I draw everything up: the eyes are up, the ears are up, and even the nose is up. When he is defeated, on the other hand, everything turns down. You can't do that as dramatically with human beings, although the emotions expressed are fully human.

Charles "Chuck" Jones

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