Gameplay Aware Emotional Model for Virtual Characters in Video Games

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Abstract

Video games today are betting more and more in creating immersive gaming experiences in order to stand out from the fiercely competitive market in which they exist. Betting heavily on animated cutscenes, voice actors and careful animation, video game designers fail to account for dynamically happening events – in dismissing these the player's character becomes, when outside of an animated event, a soulless puppet, breaking immersion and believability. We aim to improve play-through experience by creating a dynamic emotional model fitted to the player's character. In order to do this, we proposed a solution of a dimensional emotional model that maps relevant gameplay content into two dimensions of expectation and valence. This proposed solution was tested with a sample of 61 people. From the results we managed to conclude that there was a statistically significant increase in how the player perceived his character's perception of past, present and possible events when compared with the video game industry standard, promoting a better gameplay experience.

Introduction

Affective video-games receive increasing attention, as the gaming community identifies the importance of emotion in creating better games (Gillead, Dix, and Allanson 2005) - the growing area of affective computing has much to add to the creation of video games both for entertainment and 'serious' purposes.

But why are emotions important for video games?

Emotions have impact on human decision-making, sociality, perception, memory and creativity (Ariely 2010). They, therefore, play an important role in creating a believable virtual agent (Bates 1994) – agents that provide an illusion of life and permit the user's suspension of disbelief (the notion that the implausibility of something can be suspended for the sake of enjoyment). In video games they should be used both as a basis for more consistent behavior of game characters, but also a way to develop more complete models of the players themselves, to enable dynamic affect-adaptive gameplay, and to enable the game system to induce emotions in the players (Hudlicka 2008).

Expressing emotion in animated characters has been a goal of animators since the beginning of the profession[6] and in animating a cartoon character the animator need but concern himself with the external look – the expression of the character – being that in making a believable agent, one that by definition has to have autonomous behaviour (Russell and Norvig 2003), other concerns arise such as how to accommodate the dynamic nature of its autonomy with the need to endow it with emotions in order to make it more believable.

There is much work in endowing believable agents with emotions (Gebhard, Baur, and Darnian 2014) (DeVault et al. 2010) and another focus today in affective computing lies also on reacting to the user's own emotions (Rudra 2005) - Gilleade et al. (Gillead, Dix, and Allanson 2005) distinguishes even some of the directions present today in making affective games[1] of this kind, as those that focus on detecting player frustration and attempt to assist them; games that detect boredom/excitement and attempt to adapt game difficulty in order to prevent a boring play-through and; games that track the player's emotional response to specific game content adjusting subsequent content to provide a more engaging experience. But, as Hudlicka (Hudlicka 2008) points out, another more specific area of affective gaming is being almost neglected by comparison which is gifting emotional models to in-game characters – specifically, as will be shown, the player's character – merging important areas of focus in affective computing. By ignoring dynamically occurring events, which are relevant to the player and his character, video game developers are

1- video games that have an interchange of affective signals between the player and the game itself.

lowering immersion and believability. As Joseph Bates points out, “the emotionless character is lifeless, as a machine” (Bates 1994) and it's a problem that repeats itself, as will be shown, on most video-games today.

This isn't to say there is no emotional content already present in modern video games (Mass Effect, Bioware, 2007) (The Sims 4, EA Maxis, The Sims Studio, 2014) (The Witcher 3: Wild Hunt, CD Projekt RED, 2015), as much is already being done to achieve emotional expressions in video games – any solution to be implemented would have to account and work in tandem with what is already being done in, to not supplant or substitute work but to add to it.

We aim to present a possible solution to the previous problem by proposing to use an emotional model, to be applied to the player's character. By doing so, the emotional model interprets the player's actions and in-game events allowing to express believable and consistent behavior, akin to that of a human being, leading to a more immersive experience.

In order to test this hypothesis, the Gameplay Aware Emotional Model – or GAEM - was implemented, and users were asked to play one of two identical video-games, where only one used GAEM, afterwards filling out a related questionnaire – following a formalized model of immersion we determine if the game experience improved, and how.

Affect in video games

Commercially the focus has been of attempting, to some level of success, to endow non-playable characters (NPCs) with emotional components in the hopes of making a more immersive playthrough experience.

Traditionally this takes on the form of a number reflecting approval/disapproval of the player's character, which in turn would be normally tied to game objectives – obtainable in an easier fashion should a particular NPC's approval rating be satisfactory. This number reflecting approval/disapproval can be hidden (Knights of the Old Republic, BioWare, 2003) or accessible to the player (Dragon Age: Origins, BioWare 2009).

This system can also be applied to entire groups of NPC's – traditionally called factions. On video games that allow the player a high degree of liberty in choosing allegiances, normally associated with more dynamic non-scripted games, a faction system is usually implemented to keep track of groups that are hostile or friendly towards the player's character or party (Eve Online, CCP Games, 2003) being that implementing a faction system is also an easy way of determining NPC hostility to other characters besides the player (Skyrim, Bethesda Game Studios, 2011).

As for the player's character, commercially, the trend has been in either not pursuing an emotional component at all (Hammerwatch, Crackshell, 2013) or in creating pre-scripted emotional responses, usually via the use of cutscenes in video form (Final Fantasy XIII, Square Enix, 2009) or in real-time (Mass Effect, BioWare, 2007) – these emotional responses would normally be always the same, given the same player dialogue choices. Alternatively part of player character's emotional state can be inferred through dialogue choice options (Neverwinter Nights, BioWare, 2002). Another common approach, which is already more related to the dynamic event capture proposed here, involve trigger events starting a specific emotional display – for example should the player not do anything, Sonic (Sonic the Hedgehog, Sega, 1991), would tap his feet displaying boredom.

Another example that falls outside the norm but would be remissive not to mention are the life simulation games 'The Sims' is a prime example of a video game attempting to emulate individuals and relationships (Rollings and Adams 2006). Since it's a simulator of human beings all emotional content isn't pre-scripted and will depend entirely on gameplay, and its most recent iteration,(The Sims 4, EA Maxis, The Sims Studio, 2014) has introduced for the first time an emotional model2 based reactively on triggered events. For example a character may become angry should he eat Angry Flaming Spaghetti or sad if he loses a family member. The model created is very specific to the simulator though (and like the dynamic event capture in Sonic, is purely reactive in fashion), so even if it's the most relatable work in terms of commercial games it's too specific to the game for any form of formalized comparison.

Computable Emotions

Having determined the importance of emotion in creating believable agents, it is important to be objective in its definition, but the exact definition regarding what emotion is or isn't is subject of much debate to this day (Kleinginna and Kleinginna 1981) - although much work exists in the psychology of emotion, there is no singular definition used for it (Chapman and Nakamura 1998); in fact there seems to be quite the opposite: Kleinginna and Kleinginna, (Kleinginna and Kleinginna 1981) compiled ninety two disparate definitions for emotions, not including their own, into distinct categories pertaining to the more basic psychological theory they supported (affective, cognitive, physiological, adaptive, and so on..) Leading to the apparent conclusion that there is no conclusion on the matter of defining emotion. However among the disconsensus pertaining to the details of the definition there is reasonable consensus of the view, that emotion is considered by most theorists, "as a bounded episode in the life of an organism, characterized as an emergent pattern of component synchronization preparing adaptive action tendencies to relevant events as defined by their behavioural meaning and seeking control precedence over behavior." (Scherer, Banziger, and Roesch 2010).

Computable emotions

Scherer, Länziger and Roesch (Scherer, Banziger, and Roesch 2010) categorized affective models categories into five separate general categories, differentiating themselves in what particularity they wish to convey special relevance or the psychological theory they are backed by. Of those, we analyze the two most common.

Appraisal theory approaches

Appraisal theory postulates that all emotions come mostly from our own interpretations of events – our appraisal of a situation is the emotional response (Lazarus 1991). The theory focuses on the difference in reaction to seemingly similar stimuli, blaming our own judgment as source of our emotional response. Focusing on the individual and its psychological response, appraisal theory is best used in connecting awareness with emotion. Many virtual emotional models which opt for the appraisal theory approach oft base themselves on the emotional classification in 'The Cognitive Structure of Emotions' (Ortony, Clore, Collins, 1988) which states that emotion is structured into the categories of Fortunes-of-others, Prospect-based, Well-Being, Attribution and Attraction, or more largely grouped into consequences of events, actions of agents or aspects of objects (usually referred as the OCC model in lieu of the model's authors). There's certainly some overlap between the OCC model and items considered relevant to the model (such as the having a section of our model dedicated to prospect-based emotional content) but the OCC attempts to incorporate all emotion – emotions such as attraction, or pity. The focus of the model to be implemented is to increase immersion and believability by dynamically model emotions in response to events traditionally dismissed by game developers but nonetheless relevant to the player and the player's character. As we saw on the commercial games analysis, traditionally more complex emotional states, such as love or pity, are given special attention and pre-scripted into the game itself. Despite being one of the most used models in affective computing, were the OCC model to be used, it in its entirety it would either remove part of the pre-scripted events, mentioned previously, that usually add complexity and emotional content to video game characters, or only part of the model would be used. Moreover the OCC model doesn't relate emotions between themselves, except categorically, (making it very appropriate for an appraisal-based model). An appraisal theory approach is usually the one dominant in the community of computational emotional modeling (Picard 2000) and there is a potential in using such a model for more static NPC/environment emotional association. The appraisal link is almost always present in emotional models but, as we will see, there are other approaches focus on other facets, perhaps more relevant to test the hypothesis.

Dimensional theory approaches

The dimensional approach focuses on the connection between affective states and on its origin as a combination of an n-dimensional vector (related also to the appraisal variables of appraisal theory). James Russell (Russel 1980) created the first dimensional models, postulating that any affective state could be created by a combination of pleasure/arousal, or respectively misery/sleepiness. Russell opted to represent each dimension on a base-3 order being that the amount of possible emotional states given is three to the power of two – nine, if one counts with he neutral state. Many other dimensional models have, since then, been created, such as PAD (Mehrabian 1980), being that usually valence (pleasure/misery) and arousal (aroused/sleepiness) seem to be the more consensual ones (Picard 2000). Unlike the appraisal theory mentioned earlier Russell also builds upon the concept of core affect (Russel 2003), which translates more or less directly (Scherer, Banziger, and Roesch 2010) into his first proposed dimensional model of valence and arousal, commonly referred to as a feeling that is, in itself, object free (i.e. without an associated appraisal). One quickly concludes that a big advantage of the dimensional approach is one can attempt to code the seemingly complex nature of human emotions as a combination of simpler internal factors. Moreover that they are intrinsically connected between themselves as combinations of other internal factors. Whereas the appraisal approach attempts to associate an emotional state with specific appraisals (for instance eating a cake <<>> happiness) the dimensional approach seeks describe the emotional state of the individual as a subset of other variables, making it a good choice for GAEM.

Immersion

As Calleja (Calleja 2007) points out, immersion is poorly defined in the academic community, with disparate definitions being all too common. As improving immersion is key to the GAEM a clearer definition should be used as to provide objectivity. Calleja (Calleja 2007) proposed a conceptual model that replaces the metaphor of immersion with one of incorporation. This metaphor signifies an internalization of the digital environment that makes it present to the participants consciousness as a domain for exerting agency while simultaneously being present to others within it through the figure of the avatar (Calleja 2007). He therefore broke down what is commonly referred to as immersion and presence into a model of six different dimensions, each pertaining to the player's involvement in a macro and micro involvement frame – macro referring to general motivation and micro referring to focused deep involvement in the video game.

Affective involvement: Focusing on how compelling a game is, from an emotional arousal viewpoint – not that it elicits a particular emotion but that it engages the player in excitatory homoeostasis.

Spatial involvement: Focuses on game's component of exploration – ie. How much a game satisfies the player's desire to explore a different world.

Tactical involvement: Pertains to working and achieving in-game goals.

Per formative involvement: The motivational drawn by the ability to perform within the virtual environment – to act within the limitations of the game-system.

Narrative involvement: Focusing on the narrative component of the game, enriching gameplay by having a compelling in-world story.

Shared involvement: This section is mostly reserved for massive-multiplayer-online games and refers to a crucial motivator pertaining to the social component associated with playing these games, but also with interacting with non-player characters.

GAEM

Our model was designed with the goal of improving immersion, believability and ultimately the game-play experience by adequately modeling the player character's emotional state and conveying it. In order to achieve this goal, it became important that our model be aware not only of what was happening in real time in the game world but also what had happened previously – there would be a need to sift through all the information gatherable from the game state, and from it express an emotion to the player. As the model should be adaptable to most video games we propose a separation of both the game and the model, with minimal invasiveness to the core structure of the game itself. Being independent from the game architecture itself, this emotional model works by offering, per game frame, a possible emotional expression based on its current and previous data. So the exchange between the two is simple: the game is responsible for sending relevant information to the model, in the form of events and belief updates, as they happen, and the model is responsible for sending an expression (and any other information the game designer wants) back to the game. Events can be categorized as distinct “things” that happen in the game, which are deemed (by the game designer) relevant to the emotional state of the character, such as losing health points or receiving a big pile of treasure. These are discreet and atomic in nature and, although they may have an external source, they are usually linked directly to the internal state of the avatar itself – a good example of this is loss of health points, but they could also be related to what the avatar is currently seeing. Belief updates, on the other hand, are more complex in their nature and require a greater analysis of the game itself. Whereas events are focused on the internal state of the avatar, belief updates are focused on interactions between the character and the world – how a particular experience, be it good, bad or a mixture of both, affects how the avatar feels about a particular object or thing. This requires a greater analysis of the game because it's not simply a matter of listening for changes in a specific variable but analyzing the game state to determine what constitutes an episode or a full interaction that reflects ultimately in a reward or a punishment and how this episode, or interaction, changes the avatar's perceptions of the object or thing in question. Because not that many games start with game characters that are complete blank slate in terms of memories and emotions (usually offering some sort of past and personality), it is also important, in order to achieve better responses, to implant “artificial” memories and personality, tweaking the emotional model itself, in order to create a cushion or pillow for the character's emotions. This step allows the player or the game designer to further customize their game character before even starting the game itself, contributing to a more immersive experience.

Unexpectedness Calculator

Skinner introduced the notion of operand conditioning (Skinner 1938) - that our judgment of anything takes into account our own expectations of reward – which finds its way into video-games in the link between effort and reward, be it the player's or their character's. GAEM should then reflect not only the direct rewards the player and his character receive, but also the character's own expectation of reward. Following work in (Martinho 2007), valence aside, it affirms that the unexpectedness of an event leads to a stronger emotional response. One of the first steps after receiving a new event is calculating the degree of abnormality or unexpectedness of such an event. In order to do this it was opted to assume, based on the central limit theorem, a normal distribution pattern for all event inputs. This inference provides, in most cases, the smallest amount of error whilst offering statistically valid conclusions. This approach also follows the design premiss to keep both game and model as separate as possible. So, following the premiss of a normal distribution, the unexpectedness is given by the standard score, or z-score of an input (which is calculated via a weighted average and variance supplied by the event record module).

The game designer may then determine an appropriate number to translate this into the expected /unexpected binary. In a preliminary stage of the testing scenario, upon demonstrating several of the options to a small group of people, we considered that any event with an unexpectedness above 0.67 should be classified as unexpected (but it can be customized to emulate a character that is difficultly impressed, for instance). After the calculation are done the new value is added to the event record itself.

Event Record

Memory in our model is handled by two different modules, this one being responsible for storing appraisal-free data, through the eyes of the avatar. It is responsible for supplying our avatar with a memory of past events, in order for it to know what to expect. The other important segment of the avatar's memory – the appraisal part - is handled by other module altogether – object memory and appraisal selection. So one module attempts to be more analytical and store, in its view and without an affective component, what happened, whilst the other is responsible for storing memory of beliefs and picking an appropriate appraisal. Because of the processing and storage concerns related with calculating standard deviation for each new value, an online algorithm was implemented that would calculate variance – this approach ends up being less demanding, from a performance perspective, as it minimizes record keeping and processing requirements. By using this algorithm no permanent record of previous events is required and the average and variance are still available to label events as expected/unexpected, having only the requirement that there should be a recurrent relation between the numbers involved in each event. Keeping in mind that memory is proportional to the affective component associated with it and that it is not the objective of this model to simulate human memory, but simply to account for some of its affective components, it was opted to, instead of calculating a traditional mean, to assign a weight to each new event memory – to account the associated affective importance.

Appraisal Selection

Following the work of FatiMA(Paiva 2005) a valence type opinion mechanism was created where -1.0 would mean extreme dislike and 1.0 would mean the opposite (naturally 0.0 would constitute lack of opinion or indecision on the subject). Following this, each event type has an associated appraisal that stems from the character itself, but there are still two main types of appraisals. The first type relates to how the character feels about changes in its internal state. As they are considered part of the character's personality, it stands to reason these values should/would only be changed by scripted events – the same way the initial character's personality is given to the model. The second type of appraisals relate to the charac

ter's opinion pertaining to the world around him. As such it requires an auxiliary module that will provide appraisals on objects types. These are dynamic and depend on the character's interactions with the object itself.

Object Memory

Object memory was added to the model to account for more complex affective interactions between the character and the world around him. Picking up on the previous event memory implementation, the model allows to create a dynamic memory appraisal model for any type of "object". It does so in the following fashion: For any type of item desired, the model creates an appraisal which is, initially, neutral and will respond to the character's interactions with it, which can be good, neutral or bad towards the character. Based on a reward/punishment duality a weighted average is used to update the belief of the character of that particular object. Like the event records this weighted average attributes greater relevancy to more recent interactions. In short, object memory weighs the pros and cons of past experiences, giving more relevancy to more recent experiences and will then provide an associated valence.

Emotion Selection

Previously we had discussed the work of Thomas and Johnston (Thomas and Johnston 1981) - their considerations hint at the use of simple expressions, instead of several emotional expressions of variable degree – thankfully this approach works well with the core affect model being used and the dimensional theory behind it, that already synthesizes the complexity of human emotion as a product of, in this case two, dimensions, valence and unexpectedness. Using the work by Hammond (Hammond 1970) and Martinho(Martinho 2007) as a basis, the following mapping between stimulus and emotional response was observed:

	Less than expected	Within expectation	More than expected
Good	Distress	Happy	Hope
Bad	Relief	Sad	Fear

Affect Selection

The affect selector contains primarily a buffer with all the received affective stimulus and is responsible for picking out an expression to send back to the game. Generally speaking, from all the stimuli present in the buffer, following the reasoning that the stimulus responsible for the most intense emotion should be the prevalent one, an appropriate expression pair is sent to the game to handle expression.

Evaluation

Testing such a model requires primarily a game to use it on and, naturally, a user sample to test it on. Testing the model on a full, modified, game might create tests that would take too long and thus reduce the sample size available for testing – it would also limit testing to the game chosen which might be less than ideal. So it was opted to create a small video game episode, in Unity, with the model in tandem – this is the most efficient route as it minimizes superfluous programming whilst still providing a valid testing scenario. This chosen video game episode to evaluate the model was, as examples discussed previously, a rogue-like game with minimal back-story and game mechanics. Since we mean to test whether this model is a new significant improvement, immersion wise, to the current industry standard our first step was to determine a proper control group to which to compare our model against. Following our previous video game analysis, in particular to roleplaying games or even dungeon-crawlers, we created a control group which was in every way equal to the testing scenario with the very important difference that all affective processing, instead of using GAEM, is done by the usual techniques – either pre-scripted or reactive. All affective responses in the control scenario are, therefore, preconditioned. The character was purely reactive, exhibiting always the most recent affective stimuli in always the same fashion (so, fear for traps, happiness for coins and so on). Test subjects were asked to follow a link, online or in situ, which forwards the user randomly to one of two identical questionnaires which help to profile them. Users were asked gender, age gap, weekly video game habits and finally familiarity with role playing games, following which they played through one of the two games described. Afterward, they were asked how much they agreed or disagreed (Likert scales 0 to 5 with a neutral option in 3) with a series of statements:

- The player avatar (the game character) is aware of its surroundings.
- It is easy to understand where the player avatar is focusing its attention on.
- The emotions of the player avatar are easy to understand.
- It is always clear what caused an expression of emotion in the avatar.
- The expression of emotions is consistent with what the player has done in the past.
- The expression of emotions is consistent with what is happening in the world at the time.
- The expression of emotions is consistent with what the player avatar is expecting to happen.

Results

Testing involved a sample of a total of 61 users, with ninety three percent of applicants were sixteen to thirty five years old and offered a gender ratio of (approximately) 5:1 male to female. Most of the sample is already familiar with a video game setting and experienced with RPG games, which should help to mitigate a possible learning curve and possibly bring a more critical input to the results. Since none of the distributions were normal a non-parametric analysis was performed, via a Mann-Whitney U-Test the analysis of which revealed a statistically significant shift ($p<0.05$) from the reactive model to GAEM in the last three Likert Variables – those that relate to perception of time. The results also show that, when it comes to the comparison between the reactive model and the emotional one, there is a significant improvement on how the user's avatar relates past, present and future events. This was expected as one model has a memory component whereas the other has none – the difference allows the character to take into consideration what happened in the past, what is happening in the present and what might happen in the future, therefore contributing to a more believable character. The results also suggest that, in having a better emotional model we create a better affective involvement by eliciting better emotional responses from a video game character and consequently the player. We can also influence tactical involvement – as the players decisions and game-play influence its character's affective state, which, in turn, influence in-game performance, creating a whole new layer of additional tactical game-play. Performative involvement is also better as, as said previously, a whole new layer of character depth is added – character depth which can be controlled via gameplay. Finally it may also change narrative involvement as the character's non-scripted, non-reactive behavior can lead to emergent, previously unknown, behavior and consequently a better (or worse) narrative. We conclude therefore that the model may impact in a positive fashion on three of the six dimensions of the immersive experience described by Calleja, possibly increasing believability when compared to the industry standard in video games.

References

Ariely, Dan: “Predictably Irrational, Revised and Expanded Edition: The Hidden Forces That Shape Our Decisions”, HarperCollins, 2010

Bates, Joseph: “The Role of Emotion in Believable Agents”, Communications of the ACM Special Issue on Agents, April 1994

Chapman and Nakamura. “A bottom up view of emotion”. ASSC seminar, 1998

David DeVault, Ron Artstein, Grace Benn, Teresa Dey, Ed Fast, Alesia Gainer, Kallirroi Georgila, Jon Gratch, Arno Hartholt, Margaux Lhommet, Gale Lucas, Stacy Marsella, Fabrizio Morbini, Angela Nazarian, Stefan Scherer, Giota Stratou, Apar Suri, David Traum, Rachel Wood, Yuyu Xu, Albert Rizzo† , Louis-Philippe Morency, “SimSensei Kiosk: A Virtual Human Interviewer for Healthcare Decision Support”, AAMAS 2014

Thomas, Frank and Johnston, Ollie: “The Illusion of Life: Disney Animation”, Abbeville Press, 1995

Calleja, Gordon: “Digital Games as Designed Experience: Reframing the Concept of Immersion” Doctoral Thesis at Victoria University of Wellington, 2016

Hammond, L.: “Conditioned emotional state. In Physiological Correlates of Emotion.” Academic Press, 1970

Hudlicka, Eva: “Affective computing for game design”, GAMEON-NA 2008

James Russel, “Core Affect and the Psychological Construction of Emotion”, Psychological Review, 2003

K. Gilleade, A. Dix and J. Allanson: “Affective Videogames and Modes of Affective Gaming: Assist Me, Challenge Me, Emote Me”, DiGRA 2005

Klaus R. Scherer, Tanja Banziger, Etienne Roesch, “A Blueprint for Affective Computing: A sourcebook and manual”, Oxford University Press, 2010

Kleinginna, P.R., Kleinginna, A.M: “A categorized list of emotion definitions, with suggestions for a consensual definition”, motivation and Emotion, Vol 5, No. 4, 1981

Martinho, C.: “Emotivector, Mecanismo Afectivo e Anticipatório para Personagens Sintéticas”, Volume 5225 of the series, Lecture Notes in Computer Science, 2007

Mehrabian, Albert “Basic dimensions for a general psychological theory”, Oelgeschlager,Gunn & Hain Inc, 1980

Patrick Gebhard Tobias Baur Ionut Darnian: “Exploring Interaction Strategies for Virtual Characters to Induce Stress in Simulated Job Interviews”, AAMAS 2014

Picard, Rosalind: “Affective Computing”, MITpress, 2000

Lazarus, Richard; “Emotion and adaptation”, Oxford University Press, 1991

Rollings, Andrew; Ernest Adams “Fundamentals of Game Design.”, Prentice Hall, 2006

Rudra, Bossomaier, “Cognitive Emotion in Speech Interactive Games”, TENCON 2005

Russel, J. “A Circumplex Model of Affect”, Journal of Personality and Social Psychology,1980

Russell, Stuart J.; Norvig, Peter, “Artificial Intelligence: A Modern Approach”, Prentice Hall, 2003

Skinner, B. F. “The Behavior of Organisms: An Experimental Analysis", The Century Psychological Series, 1938