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PRINCIPLES OF FUNCTIONAL ANIMATION IN INTERFACE DESIGN

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Abstract. The use of animation in visual interface design has historically been the subject of severe criticism. Reported issues highlight the tendency of designers to get carried away by the attractive nature of animation, sometimes sacrificing basic usability principles. This research aims to establish a set of principles to guide motion design decisions effectively. In the absence of closer references, the classic principles of Disney animation have been insistently looked to. This approach raises the question of whether it is relevant to apply principles designed for the entertainment of a passive viewer in the functional and interactive environment of an interface. To address this, we identify principles supported by empirical evidence or consensus among multiple authors in the literature. Additionally, we conduct a content analysis of the design guidelines of the main mobile phone platforms to extract recommendations that can be elevated to general principles. This procedure allows us to take into account the specific characteristics of interaction on mobile touch screen devices, where animation is considered a key element of the user experience. Our research culminates in the identification of nine key principles for functional animation: Functionality, Appropriateness, Attention, Coherent behavior, Stylistic consistency, Moderation, Smoothness, Duration, and Accessibility.

Keywords: *Functional Animation, Animation Principles, Motion Design, Usability, User Experience, User Interface Design.*

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1. Introduction

The use of animation in the visual design of an interface is an important field of study within the emerging discipline of motion design (Stone & Wahlin, 2018). One of the precedents for establishing the theoretical framework of this new discipline can be found in the "informal taxonomy" (Chang & Ungar, 1993, p. 46) developed by Baecker and Small (1990). Their classification of what has come to be known as "functional animation" (Ma *et al*., 2018; Vistisen, 2021) includes examples of animation that generate visual changes in the configuration of the graphical components of the interface and have a positive impact on the interaction experience.

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Animation and usability issues

The immense potential described by Baecker and Small were held back by technical issues for decades. The main obstacles were related to hardware limitations, the lack of appropriate tools and the need for programming skills in order to implement animation (Boyarski, 2018; Chatty, 1992; Hudson & Stasko, 1993; Mirlacher *et al*., 2012; Stasko, 1993).

These limitations disappeared for many applications with the advent of Flash, the animation software that transformed and headed up web and multimedia design from the late 1990s until the beginning of its decline around 2010 (Salter & Murray, 2014). The versatility of this tool resulted in an extremely fruitful period of experimentation, in which the rules of interaction design were "summarily destroyed" and rewritten (James Baker in Ford, 2019, p. 46). Meanwhile, usability experts warned of the negative consequences of these creative excesses (Nielsen, 2000, 2005) and bemoaned that recommendations, made years ago for the introduction of multimedia elements on the web, were ignored (Nielsen, 1995).

For years, animation was associated with bad practices in the field of interaction design (Head, 2016). After the Flash era, animation was considered a mere decorative, and sometimes even annoying, element (Nabors, 2015).

From stigma to a leading role

User interface design is becoming more important than ever with the spread of mobile phones (Wasserman, 2010). The small size of touchscreens and the breadth and complexity of functionalities pose a challenge for interaction designers. The "Mobile First" approach (Wroblewski, 2011), which consists of prioritising the mobile version in the design of an application rather than considering it a scaled-down version of the desktop application, has continued to govern the design process for more than a decade. Animation starts to be seen as "an integral and critical part of the digital product experience" (Cooper *et al*., 2014, p. 266), as motion design brings new possibilities for solving design problems (Blank & Kosuru, 2020). Arnold (2018) believes that prior to the launch of Windows Phone in 2012, it was unusual - neither in Windows nor in any other competing product - to devote so much attention to animation in the design of an operating system. Industry professionals point out how the importance of the design of dynamic elements has increased in recent years thanks to the possibility of creating richer and more complex animations (Guy Wolstenholme and Jon Hewitt in Stone and Wahlin, 2018, pp. 137-138). The popularity of smartphones has led to the application of the dynamic look and feel of mobile apps to other interfaces (Head, 2016), blurring the differences between mobile and desktop systems.

As users, we are nowadays constantly exposed to a multitude of animations in every single interaction we make with our devices (Biørn-Hansen *et al*., 2019; Chevalier *et al*., 2016). In our awareness of the usability problems generated in the past by the misuse of animation, this situation should put us on our guard. Although some bad practices may seem to have been eradicated, usability experts warn that "there's always someone who's ready to introduce a bad design that revives the mistake" (Nielsen & Budiu, 2013, p. xi). The problems with Apple's iOS7 can serve as an example. This version, released in 2013, used excessively fast transitions, zooms, parallax effects and other aggressively dynamic movements that caused problems for people with vestibular disorders, such as dizziness and headaches (Grannell, 2013; Head, 2020). It is therefore necessary to have some

general principles to guide designers in their decisions when configuring the dynamic elements of an interface.

Design guidelines

Design guides are one of the main sources of information available to designers when creating an application for a mobile device. As described by authors such as Novick et al. (2011) and Liddle (2016), there were few references to animation in the design guidelines of the three main platforms at the time (iOS, Android and Windows Phone). Sometimes they were limited to offering code snippets. In 2014, this trend changed radically. Google introduces motion as one of its fundamental principles in its new "Material Design" guidelines, claiming that “motion provides meaning” (*m1.naterial.io*, s. f.).

The first version of Material Design devoted an extensive chapter to the use of animation under the term "motion", referring to all those design decisions aimed at controlling the changes that occur in the visual appearance of the interface. In 2016, they incorporated detailed examples and references to the principles of motion. They provided precise information on parameters such as duration and speed in different situations, or specifications on how to choreograph the animation of several interface elements (Google, s. f.). Motion is presented as an essential feature, with greater importance than other stylistic qualities such as colour or typography (Liddle, 2016). By February 2020, they add "Material motion system" - a set of patterns to create transitions that help the user navigate and understand an application (Google, s. f.). In 2021, the third version of Material Design, called “Material You” (*M3.Material.Io*, s. f.), focuses on building emotion through motion and dynamic shapes (Ramírez, 2022).

Apple's guidelines also have a specific section dedicated to dynamic aspects. The "Animation" chapter of the iOS 10 guidelines began by stating that the “Beautiful, subtle animation throughout iOS builds a visual sense of connection between people and content onscreen" (CodersHigh, s. f.). The text matches that of a version of the guidelines captured in late 2020, the URL of which currently redirects to the new version of the guidelines. Today, under the chapter entitled "motion" the main recommendations of the previous version are taken up and expanded, stating that "On all platforms, beautiful, fluid motions bring the interface to life, conveying status, providing feedback and instruction, and enriching the visual experience" (Apple Inc., s. f.). In anticipation that the text may change in the next update, the current content has been reflected in Annex 1.

The need to define functional animation principles

Although the information in the guidelines of both platforms is becoming increasingly detailed, there are limitations to consider them as a research reference. They are online documents in continuous evolution, which makes it difficult to keep track of the textual citations and references provided by authors over time. On the other hand, recommendations sometimes aim to generate a unique style that differentiates a given platform from its competitors. For example, Apple and Android recommend applying different speeds and degrees of easing in transitions from one screen to another.

In general, practitioners follow the recommendations provided in the guidelines (Wasserman, 2010), but sometimes it is necessary to develop applications for different platforms (López-Jaquero *et al.,* 2020). Therefore, it would be advisable to extract those recommendations that can be elevated to general principles from the iOS and Android guidelines, thus creating a stable reference.

First of all, it is necessary to identify accepted rules and principles gathered from the scientific literature. In the absence of closer references, authors have insistently looked to the classic principles of Disney animation as a source of inspiration to try to extract principles adapted to interface design (Layton, 2017). This approach raises the question of whether it is relevant to apply principles designed for the entertainment of a passive viewer to the functional and interactive environment of an interface.

The twelve Principles of Animation, set out by Thomas and Johnston (1981), summarise the way of working developed by Disney cartoonists in their quest to give realism to their characters. They are the result of an important work of observation that captures the changes, often imperceptible to the naked eye, that occur on the surface of objects when they are subjected to the physical forces of nature. The emphasis applied to these deformations sometimes sought a dramatic or comic effect that succeeded in filling the characters with life and personality, thus gaining the audience's empathy.

These principles are still applied in the creation of animated characters today but, depending on the tools used to create the animation, some lose importance or need to be reinterpreted (Cuesta Martínez, 2015; Lasseter, 1987; Thesen, 2020). They are essential for anyone who wants to develop animations with the same aesthetics as those used in Disney films (Pertíñez López & Alonso Valdivieso, 2018, p. 403). Therefore, they could be directly applied in the design of an avatar or a virtual agent. But it is important to bear in mind that when using animation in the design of an interface "we are sketching interaction, not making Toy Story" (Buxton, 2007, p. 299). Like any other element of visual design, animation must be approached in terms of the goals of the interface: to help the user successfully operate the device. The principles of functional animation should be in line with the fundamental principles of interaction design highlighted by Norman and Nielsen (2010), Shneiderman's Eight Golden Rules of interface design (1987; Shneiderman et al., 2018), or Nielsen's Usability Heuristics (Nielsen, s. f., 1994).

The aim of this paper is to propose a set of principles of functional animation based on empirical evidence and the tradition of scientific literature, which take into account best practices, and whose statements are consistent with the principles of usability and interaction design.

2. Method

We take as a starting point the principles developed by Stasko (1993) as a complement to the pioneering work of Baecker and Small (1990). The articles that cite these two references are then followed up. In addition, a bibliographic search is carried out in Web of Sciences, SCOPUS, ACM Digital Library and Google Scholar, using as search terms "animation", "motion", "transition", "micro-interaction" and variants such as "animated transition", in the title or in the keywords, in combination with the appearance of more generic terms such as "design" or "interface" in the abstract. These terms are commonly used in various disciplines; hence it is necessary to narrow the search by performing several operations that consider the combined presence of the above terms with such others as "principles", "usability" or "user experience" in order to limit the number of results. This research is part of a broader investigation aimed at locating the main milestones in the use of animation throughout history. To this end, more than 2,400 references were reviewed, including non-scientific literature, video recordings and blogs. This allows us to reach a global vision of the principles and guidelines that have been used not only in scientific research but also from an applied perspective. We have

consulted material ranging from the design guidelines of the first computers with graphical user interface to articles published in leading industry blogs such as Medium, UX planet, UX Collective, Interaction Design Foundation, Fast Company, A List Apart or Smashing Magazine.

This extensive literature review is complemented by an analysis of the best practices contained in the design guides of the two platforms that currently dominate the mobile phone market: Apple iOS and Android. With regard to the latter, we analysed the content of the current guidelines as well as the two previous versions, which can be accessed from the online archive on the Material Design website. As for Apple iOS, the current version is analysed as it includes and expands on all the concepts present in the previous one. The results are used to draw up a list that will serve as a reference to locate coincidences with the statements present in the scientific literature.

Finally, a set of principles is established that includes those statements supported by the criteria of various authors or by empirical evidence, summarising the fundamental concepts gathered during the research.

3. Results and discussion

Principles drawn from the design guidelines

In the first version of Material Design (*m1.naterial.io*, s. f.) the guidelines focus on speed, clarity and consistency. They explain that the user should never have to wait longer than necessary, transitions should avoid complexity and the use of animation should be consistent throughout the application.

In the second version, three principles are set out: Informative, Focused and Expressive. The first one states that “motion design informs users by highlighting relationships between elements, action availability and action outcomes”. The second one indicates that “motion focuses attention on what's important, without creating unnecessary distraction”. The third claims that “motion celebrates moments in user journeys, adds character to common interactions and can express a brand’s style” (*M2.Material.Io*, s. f.).

The heading given over to principles disappears in the third version of Material Design (*M3.Material.Io*, s. f.). As a subheading of the "motion" section, the sentence "Use motion to make a UI expressive and easy to use" is displayed. Under the heading "Takeaways", a set of recommendations is offered. Firstly, the use of a certain type of easing, called "emphasized", is encouraged. Compared with the more functional easing recommended in the previous version, the “emphasized” easing turns out to be more expressive. It features fast take-offs and very smooth landings, while the duration increases to prevent transitions from feeling abrupt. Next, they point out that the design of transitions is a priority, as it is closely linked to usability. Finally, they recommend considering implementing a reduced motion setting to ensure that accessibility needs are met. The motion chapter contains a section entirely given over to transitions and another to easing and duration. In these sections, there are very concrete specifications on the characteristics of motion in different situations. For example, an element moving inside the screen will pick up speed quickly and then slow down smoothly, while an element that is initially outside the screen will enter at full speed and then land smoothly.

Apple's guidelines point out that the system components automatically include motion to provide a consistent experience across applications. Therefore, when creating custom designs, they recommend focusing on animations that help people use the

interface without overwhelming them. They then offer a list of best practices summarised under the following statements: "Use motion to communicate", "Add motion purposefully, supporting the experience without overshadowing it", "Make motion optional", "Strive for realism and credibility", "Prefer quick, precise animations" and "In general, avoid adding motion to interactions that occur frequently" (Apple Inc., s. f.).

Table 1 lists the concepts found in iOS and Android guidelines, reformulating the statements. For example, the current version of Material Design recommends "Consider implementing a reduced motion setting to accommodate accessibility needs". Apple refers to the same concept in the statement "Make motion optional" and explains that "when the Reduce Motion accessibility setting is on, be sure to minimise or eliminate animations". The overlap in the recommendation is summarised in the terms of statement E6 in Table 1.

Table 1. Summary of recommendations located in iOS and Android design guidelines

E1	Animation should be informative and purposeful; gratuitous and unjustified use should be avoided.
E2	Animation should focus attention, guiding the users and helping them to keep in context.
E3	The animation should be in accordance with the user's actions and follow the laws of physics, reinforcing the feeling of direct manipulation.
E4	Animation should be expressive, bringing a particular character to the interaction.
E5	Animation should help maintain consistency across the application and the operating system itself.
E6	It should be possible to disable or minimise animation to avoid accessibility problems.
E7	Animation should be of adequate duration, preferably short and precise, so as not to keep the user waiting.
E8	Animation overuse in frequent and repetitive interactions should be avoided.

Principles defined on the basis of traditional animation

In order to make it easier to follow the arguments offered by those authors who start from Disney traditional animation when establishing principles of animation in interface design, a brief description of the twelve classic principles is given in Annex 2.

Chang and Ungar (1993) describe the interfaces of the time as essentially static, with no transitions at all from one state to another. Drastic changes disorientated users, who had to bear a significant cognitive burden to deduce the relationship between the visual configuration of the interface before and after the interaction. As they see it, cartoons, despite being a passive and frivolous entertainment, could bring inspiration to create smooth transitions, thus making the interactive experience more enjoyable. To apply their theory, they regroup several of the classical principles into three main principles:

1. Solidity. The principle of solidity refers to realistically representing the movement of objects, thus creating the illusion that the interactive elements are not simply an image on the screen but physical objects that can be manipulated. This principle brings together concepts present in the classic principles of solid drawing, slow in and slow out, follow through and arcs.

2. Exaggeration. Chang and Ungar note that cartoons achieve a more realistic effect by exaggerating actions. The application of the principles of anticipation, and some uses of follow through, while not necessarily in accordance with the laws of physics, create an illusion of reality that is essential to keep the user connected to what is happening in the interface and prevent important events from being overlooked.

3. Reinforcement. They describe the principle of reinforcement by alluding to the principles of slow in and slow out, follow through and arcs to enhance the sense of reality. In this case, they point out that in cartoons the audience is not consciously aware of these effects but perceives a sense of realism in the action.

The definitions of the three principles are thus all about the illusion of reality. It is striking that the first recommends faithfully following the dynamics of real physics, while the second speaks of exaggerating them, and the third of enhancing the sense of reality through effects that go unnoticed. This makes sense given the variety of situations in which animation can be presented in the interface. It is reasonable that in an urgent and punctual notification, the principle of exaggeration is considered, while the principle of reinforcement is more relevant in the small, almost imperceptible animations that some systems introduce at each touch on the screen.

The authors point out that while cartoons are meant to entertain and amuse, the interface is a tool that allows users to perform a task, so the animation should be as fast as possible within the limits of readability and in no case slow users down by making them wait for the animation to end before moving on to the next interaction.

In their notes about implementation, the authors make an allusion to the quality of execution which, although not stated as a principle, seems important to highlight. They note that, perhaps because animated objects seem more real, any glitch or inconsistency in the animation can totally divert the user's attention from the task at hand to the mechanics of the interface.

Thomas and Calder (2001) share Chang and Ungar's (1993) view in discussing the benefits that can result from applying classical animation techniques to interfaces, pointing out that, until then, few user interfaces had made use of these techniques. The authors aim to improve visual feedback by avoiding abrupt transitions and reinforcing the illusion of direct manipulation, providing a sense of substance and including cues that allow users to anticipate the outcome of their interaction. The authors set out the four principles developed during their research, which are set out verbatim below[†] (Thomas & Calder, 2001, p. 203):

1. *The principle of attachment* states that the objects being manipulated should at all times remain attached to the pointer, which maintains the impression that the user is always in control of the action.

2. *The principle of reluctance* states that objects should, in general, seem reluctant to change, which reinforces the illusion of substance by suggesting that changing an object requires effort on the part of the user.

3. *The principle of smoothness* states that objects should change in a continuous fashion, which reduces cognitive load by removing large and unexpected changes in visual information presented to the user.

4. *The principle of anticipation* states that the result of a user's action must be obvious at all times, which reduces cognitive load by supplying additional visual information and minimizing the use of short-term memory.

Liddle (2016) analyses the design guidelines for iOS, Android and Windows in an attempt to draw connections to the seven principles defined by Thomas and Calder (2001) and Chang and Ungar (1993). He finds examples that refer to the need to show an illusion of reality, but stresses that he had difficulties in establishing connections, even tangential ones, to the principles of solidity, exaggeration or reluctance. Nor was it easy to trace the

[†] Text shown here in italics is highlighted in bold in the original.

principle of anticipation. He observes that the terminology used in the seven principles is not reflected in the descriptions of animation in the design guidelines. On the other hand, he points out the presence of a concept that is absent in these seven principles, which refers to maintaining consistency between the animation style of an application and that of the mobile platform itself.

Dragicevic et al. (2011) argue that animation for graphical user interfaces is an area that has generally been dominated by the principles of classical animation. However, they consider that there is no empirical evidence to support the fact that these principles are directly transferable. From their study, they derive that slow-in/slow-out pacing is the most accurate form of temporal distortion when visually tracking the translation of a point cloud on screen. The results of Dragicevic et al. (2011) seem to contradict Android's recommendations that objects entering the screen should use progressive deceleration or, on the contrary, adopt an ever-increasing velocity when moving out of frame from a static position. It should be noted that the elements analysed by Dragicevic et al. (2011) were initially already in the frame and are moved to another position on the screen. Taking into account the empirical studies cited by Nishida et al. (2018), analysing the extent to which variations in direction and speed capture our attention and how these parameters influence the perception of motion, both approaches may be correct. Sometimes the animation should help the user to follow a graphic element, but at other times its purpose may be precisely to draw the user's attention immediately to another point on the screen. This is the case of an urgent notification that requires the user's action immediately. Therefore, the execution of an animation and the adjustments in terms of speed, duration or other attributes of motion, may differ depending on the communicative purpose.

Merz et al. (2016) conducted a pilot study aimed at analysing the extent to which the use of different styles of animated transitions, based on the application of different principles of classical animation, affects the perceived user experience on mobile devices. In their study, they present a series of transitions based on three conditions to participants. The first condition follows the principle of slow in and slow out. The second condition of the experiment seeks to reflect the principle of exaggeration in the sense of Chang and Ungar (1993), by combining the classical principles of anticipation and follow through with slow in and slow out. Finally, the third condition of the experiment presents a transition developed at constant speed. As this was a pilot study and due to the low number of participants, they cannot provide statistically relevant results, but they note that the data suggest that transitions using the first condition are more attractive, while those in which the exaggeration principle has been used are the least valued.

Principles developed beyond traditional animation

Stasko (1993) offers a completely different approach. He only cites traditional animation to explain that interface animation has nothing to do with cartoon films and television shows. He proposes his principles of appropriateness, smoothness, duration/control and moderation as a complement to the work of Baecker and Small (1990) in which they list eight significant uses of animation in interfaces.

The first of Stasko's principles - appropriateness - stipulates that the objects included in an animation must represent entities of the application, and the actions in the animation must adequately represent the user's mental model.

The principle of smoothness indicates that, for an animation to be effective, viewers must be able to perceive its actions and movement clearly. To facilitate perception, visual changes should not be abrupt, but smooth and continuous. In addition to creating a

correspondence with real-world phenomena, the use of accelerated and decelerated movements, and even motion blur, help make the animation easier to follow.

The duration/control principle states that the duration of an animation and the control model will be determined by the purpose of the animation. Stasko describes three possible situations. Firstly, animations that represent simple and immediate operations such as selecting a file. Secondly, animations that have a direct correspondence with the status of an operation, which must show a precise chronological summary of the operation they are representing. Thirdly, animations that provide help or instructions should allow the viewer to control the speed and even pause or rewind the animation when desired.

Finally, the principle of moderation warns that, due to the daily and continuous use of user interfaces, the application of animation should be restrained, avoiding being carried away by its flashiness and attractive nature, and explains that the saying "less is more" applies to interface design (Stasko, 1993, p. 85).

With these four principles, Stasko brings animation closer to the fundamental principles of usability and interaction design. Saffer (2013, p. 99) and Cooper et al. (2014, p. 267) also refer to similar concepts when describing the characteristics that animation should have according to Google´s Android engineers Chet Haase and Romain Guy. Cooper et al. (2014) point out that the main goal of animation is to keep the user in a state of "flow": the state described by Mihaly Csikszentmihalyi in which people achieve such a degree of concentration on an activity that they become unaware of their surroundings, forgetting their problems and ignoring distractions (Cooper *et al*., 2014, p. 249). To achieve this, animation must be fast, not delaying the activity; smooth, because jerky or choppy movements suggest that something is not working properly; natural, following the laws of the real world such as gravity and inertia; simple, meaningful and easy to understand; and finally, animation should be purposeful (Saffer, 2013, p. 99).

This last point deserves special consideration. Reflection on this fundamental concept avoids inappropriate and gratuitous use, which is so dangerous for usability in the case of animation. Thus, this could stand as the first and most important principle of animation in the interface. This is, indeed, the first principle considered by Head (2016, p. 43) when setting out the “modern principles of interactive animation". Head goes on to point out other principles that are present in Stasko or Saffer, although she does not refer to them or use the same terminology. She treats each concept in depth, with clarifying examples, composing a very didactic and enjoyable work, as it is intended as an informative tool to motivate designers and developers in their professional practice. The selection made by Seelie (2019), based on an interview with Head, precisely seeks to provide recommendations that will allow those who do not have much knowledge of motion design to do a better job than the "ninety percent of your friends".

In the course notes "Animation Tricks" of the 21st Siggraph Conference, Lasseter (1994) recalls his early days as an animator at Disney. He explains that he had a list pinned to his desk of 30 notes taken by Glen Keane when he worked as an assistant to Ollie Johnston, one of the authors of the book containing the twelve classic principles of traditional animation. Point number nine of the list advises “don´t move anything unless it´s for a purpose”. Following the same concept, point number twelve states that "Everything has a function. Don't draw without knowing why". Likewise, animation should not have a place in the interface without a purpose. It must fulfil a specific function. It should be noted that the purpose may be to serve an aesthetic function (Ávila Muñoz *et al*., 2021) since, as has been empirically demonstrated, the perceived usability

of a system is closely related to the aesthetic aspects of the interface (Kurosu & Kashimura, 1995; Tractinsky *et al*., 2000).

Table 2. Summary of salient principles identified through the literature review

Principles defined on the basis of traditional animation		**Principles developed beyond traditional animation**	
Chang and Ungar (1993)	Thomas and Calder (2001)	Stasko (1993)	Haase and Guy as cited in Saffer (2013)
Solidity Exaggeration Reinforcement	Attachment Reluctance Smoothness Anticipation	Appropriateness Smoothness Duration/Control Moderation	Fast Smooth Natural Simple Purposeful

Proposed principles of functional animation

Following a thorough analysis of the sources, we further organized the collected information to formulate a cohesive set of principles for functional animation.

As a preliminary step, we discard those statements that differ from the general consensus. The most obvious case is the principle of exaggeration, whose nomenclature seems to go against the recommendations that advocate simplicity and moderate use. The term "exaggeration", which seems to invite overuse or abrupt execution, is therefore avoided. However, the essence of Chang and Ungar's principle of using animation to create an illusion of reality that connects the user to the interface and prevents important events from going unnoticed is captured. Stasko's four principles are retained while his statements are reformulated to incorporate related concepts. Regarding the guidelines stating that animation should be expressive, we consider this to be covered by several of the proposed principles. Expressiveness is essential to create an animation that adequately represents an operation or process, as covered by the principle of appropriateness. It is also critical to create an animation that is simple and easy to understand, a concept we include in the principle of moderation.

After a process of reorganising and summarising all the information gathered, we finally propose the nine principles listed below.

1. Principle of functionality: Animation must fulfil a function and have a defined purpose. Gratuitous and unjustified use should be avoided.

2. Principle of appropriateness: The animation should adequately represent the user's mental model by appropriately reflecting the actions and evolution of the processes, keeping the user in context.

3. Principle of attention: The animation should direct attention to the essentials without being flashy. It should not distract the user from the task at hand, except when it is required to divert the user's attention to the element highlighted by the animation.

4. Principle of coherent behaviour: The behaviour of animated elements must be coherent with the user's interaction, providing an illusion of realism and naturalness that reinforces the feeling of direct manipulation by relying on effects such as gravity and inertia.

5. Principle of stylistic consistency: Animation should present a consistent style in similar situations across the application, preferably following the style of the platform's operating system.

6. Principle of moderation: Animation should be simple, straightforward and easy to understand. Its application should be restrained, avoiding being carried away by its eye-catching and attractive nature.

7. Principle of smoothness: The execution must be fluid, without jerky or choppy movements that might suggest that something is not working properly, unless the animation is precisely intended to communicate a system failure, signal an error or other similar situations.

8. Principle of Duration: The duration of the animation shall be determined by the function it performs. It should be produced in the shortest possible time within the limits of legibility, without slowing down the activity and keeping the user in control.

9. Principle of Accessibility: It should be possible to disable or minimise animation to avoid accessibility problems.

3. Conclusion

This paper was driven by expert concerns regarding the inclination of designers to become captivated by the allure of animation, occasionally compromising essential usability principles. We have identified the challenges that underscore the necessity for establishing overarching principles to assist interface designers in making well-informed decisions regarding the suitable application of animation.

After conducting an extensive review, we identified authors who propose principles based on Disney traditional animation, while others offer alternative approaches aligned with the fundamental principles of usability and interaction design. Additionally, we derived recommendations from the design guidelines provided by major mobile phone platforms. This procedure allows us to take into account the specific characteristics of interaction on mobile touch screen devices, where animation plays a key role in enhancing the user experience.

Having scrutinized and discarded statements lacking evidence or consensus, we synthesise and reformulate key concepts to propose a set of principles for functional animation, encompassing Functionality, Appropriateness, Attention, Coherent behavior, Stylistic consistency, Moderation, Smoothness, Duration, and Accessibility.

Drawing inspiration from Shneiderman's eight rules and Nielsen's ten heuristics, these nine principles of functional animation aim to serve as a solid foundation for guiding design decisions. We suggest incorporating these principles into the heuristic evaluation processes to identify potential usability issues stemming from improper animation usage in interface design.

As a future work, we plan to develop an inspection method to evaluate the design of dynamic elements in terms of their contribution to interface usability. On a complementary basis, we plan to develop tools such as an evaluation scale or a checklist to help detect superfluous animations and dismiss potentially problematic approaches at an early stage of the prototyping process.

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Annex 1 - Motion chapter on iOS - Human Interface Guidelines (November 2022)

On all platforms, beautiful, fluid motions bring the interface to life, conveying status, providing feedback and instruction, and enriching the visual experience.

System components automatically include motion, letting you offer of familiar and consistent experiences throughout your app or game. As you design custom motion, focus on intentional animations that keep people oriented, provide clear feedback in response to their actions, and help them learn your interface without getting overwhelmed.

Best practices

Use motion to communicate. Motion can be a great way to enhance feedback and understanding by showing how things change, what will happen when people perform an action, and what they can do next. For example, when people minimize a window in macOS, it moves smoothly from the desktop to the Dock so they know exactly where it went; when people set up Face ID, the system briefly describes what they need to do and helps them during scanning by visually changing the tick marks encircling their face.

Add motion purposefully, supporting the experience without overshadowing it. Don't add motion for the sake of adding motion. Gratuitous or excessive animation can distract people or make them feel disconnected, especially in an app that doesn't provide an immersive experience.

Make motion optional. There are several reasons why people might not see onscreen animations, so it's essential to avoid using it as the only way to communicate important information. For example, when the Reduce Motion accessibility setting is on, be sure to minimize or eliminate animations. For guidance, see Color and effects.

Strive for realism and credibility. Accurate, realistic motion can help people understand how something works, but motion that doesn't make sense — or appears to defy physical laws — can make them feel disoriented. For example, if someone reveals a view by sliding it down from the top of the screen, they don't expect to dismiss the view by sliding it to the side.

Prefer quick, precise animations. Animations that combine brevity and precision tend to feel more lightweight and less intrusive, and often convey information more effectively. For example, when people tap the list button in Weather on iPhone, the fullscreen view of the current city quickly transitions to the list view, pinpointing the city's location in the list.

In general, avoid adding motion to interactions that occur frequently. The system already provides subtle animations for interactions with standard interface elements. Avoid making people spend extra time watching unnecessary motion every time they interact with something.

Annex 2 - Principles of Classic Disney Animation

The twelve basic principles defined by Thomas and Johnston do not present a synthetic statement, but rather offer a broad explanation based on the description of examples, often illustrated graphically. The following is a brief explanation to place the authors and their references to Disney principles in context. Various references have been used (Cuesta Martínez, 2015; Head, 2016; Lasseter, 1987; Thesen, 2020) in its preparation in addition to the original source (Thomas and Johnston, 1981).

1 - Squash and stretch. The shape of any object composed of organic material will deform during movement, regardless of its bone structure. The degree of distortion depicts the mass and rigidity of the object represented. When this deformation is taken to the extreme, the animation loses realism and takes on a comical character.

2 - Anticipation. Each action must be anticipated with a specific movement that clearly indicates the action a character is about to perform. A classic example is the movement of a baseball pitcher or a tennis player when they take momentum with an anticipatory movement in the opposite direction before impacting the ball.

3 - Staging. Each idea must be presented in the strongest and simplest way, using all the elements available to support understanding.

4 - Straight ahead action and pose-to-pose. In traditional animation, there are two possible ways of approaching the realisation of an animated sequence: drawing the frames one after the other, or drawing the poses, with the extreme moments of a movement first, and then drawing the intermediate frames.

5 - Follow through and overlapping action. This principle refers to the fact that moving objects do not stop suddenly or simultaneously. For example, when stopping walking, one foot stops before the other one and clothes and hair will keep moving even after the character has reached a standstill.

6 - Slow in and slow out. Originally related to the spacing of frames between poses, it refers to progressively increasing the speed at the beginning of an action and slowing down the movement at the end. This is intended to create an effect of realism and naturalness, as only mechanical objects can start a movement at a constant speed, without a certain prior acceleration. Excessive slow in and out also appears mechanical and unnatural.

7 - Arcs. Objects tend to move along curved trajectories, drawing arcs. This is caused by physical forces of nature or when the movement of an object is limited by a rigid structure that forces it to rotate around an axis or joint.

8 - Secondary actions. This refers to enriching the main action by complementary actions that reinforce understanding and bring naturalness and personality.

9 - Timing. Timing relates to the number of frames used to represent an action and consequently, the temporal duration of a sequence. A character performing the same action can be lazy, active or nervous depending on the time taken to show the sequence of drawings.

10 - Exaggeration. The principle of exaggeration consists of accentuating the essence of the idea to the extreme in order to achieve a more convincing effect.

11 - Solid drawing. This principle emphasises the importance of maintaining a sense of volume, weight and perspective throughout the animation, without ever losing the formal structure of the animated character or object.

12 - Appeal. The last principle underlines the importance of reinforcing the character's personality through all the elements that can capture the viewer's attention. By doing so, the cartoon character acquires the charisma of the real actors.