PEAR: Prototyping Expressive Animated Robots
A Framework for Social Robot Prototyping

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Keywords: Robot Animation, Robot Prototyping Tool, Social Robot, Expressive Robot, Animation Software, Blender.

Abstract: Social robots are transitioning from lab experiments to commercial products, creating new needs for prototyping and design tools. In this paper, we present a framework to facilitate the prototyping of expressive animated robots. For this, we start by reviewing the design of existing social robots in order to define a set of basic components of social robots. We then show how to extend an existing 3D animation software to enable the animation of these components. By composing those basic components, robots of various morphologies can be prototyped and animated. We show the capabilities of the presented framework through 2 case studies.

1 INTRODUCTION

As social robots get out of the labs and into homes, taking on new tasks and roles, the question of these robots user experience become more salient. Much of the user experience of a social is related to its appearance and how it moves. Designing appearance can be used to set expectations about the robot capabilities (Duffy, 2003) while designing movements can improve the legibility of the robot intentions (Takayama et al., 2011). Therefore these two dimensions are major in the design of a social robot. Designing the appearance and movements independently can be limited because the possible movements depend on the shape of the robot and its actuators.

(Hoffman and Ju, 2014) suggest a methodology focusing on the movement design. In a first phase, they use *paper sketches* to define the robot appearance, as a cartoonist would do to find the design of a character, and rough 3D shapes animation to define the robot's way of moving. It allows them to iterate rapidly between the design of the robot appearance and its movements. However, animating robots raises additional challenges compared to 3D animation. Robots are subject to the laws of physics. They can oscillate, shake or vibrate and their motors produce friction-related noise. In addition, their engines have speed and acceleration limits. These constraints specific to robot animation can modify the expressiveness of a movement if they are not taken into account. In (Hoffman and Ju, 2014), these constraints are taken into account in a second phase consisting in the fabrication of skeleton prototype of the robot. This step also requires the creation of a dedicated software to animate the prototype. We are proposing in this work a simplified system for this step.

The design of robot animation software has been explored in previous work (Van Breemen and Xue, 2006) (Pot et al., 2009) (Saldien et al., 2014), each time for a specific robot. A common factor is their use of concepts from 3D animation tools. Those concepts have the advantage of being already familiar to animators. We propose to go further in the familiarity and to extend an existing 3D animation software to animate the robots prototypes. Animation tools have a steep learning curve and reusing one that animators already master will make the system easier to adopt. A second advantage is that it can be used to evaluate how well different parts of 3D animation tools transfer to robotics.

Our objective is to design a general system allowing different robot morphologies to be prototyped and animated. We propose to do so by defining a set of common basic components that can be assembled together to compose different morphologies.

In section 2, we present an overview of the existing social robots design landscape. In section 3, we define categories of basic components shared by those robots. In section 4, we present the 3D animation software Blender and an overview of its features. In section 5, we describe how our system map Blender features to animate different components categories. Finally, in section 6, we present 2 case studies of robots animated thanks to our system.

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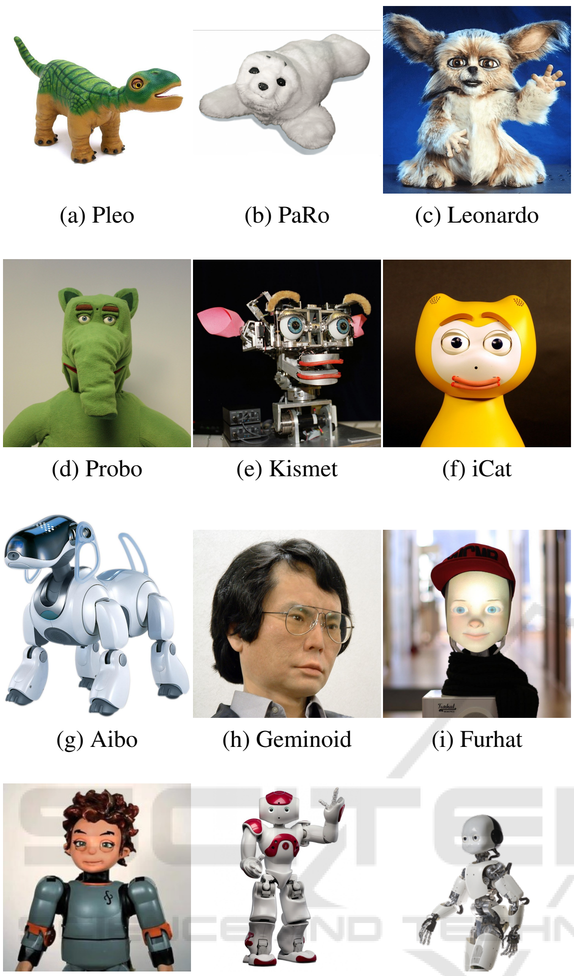
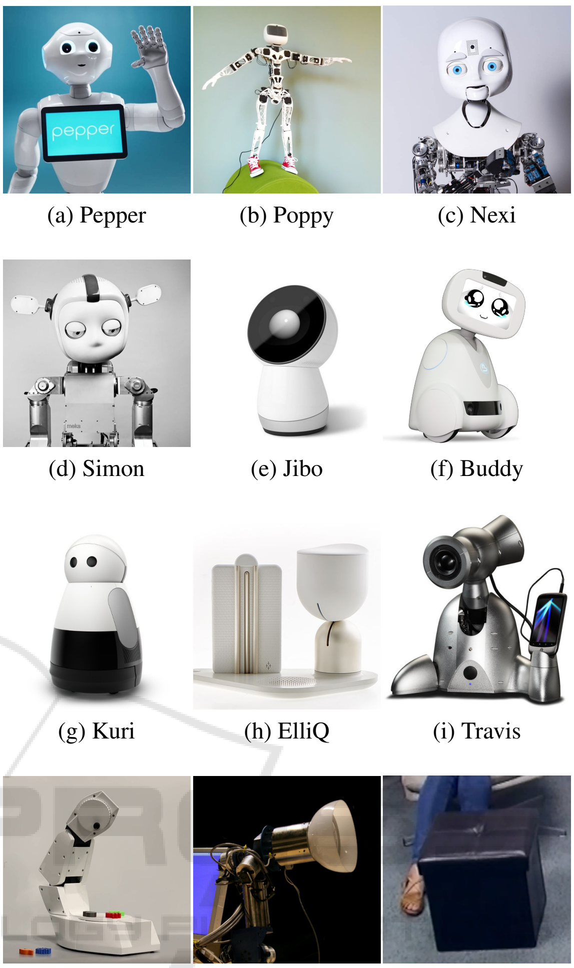


(a) Pleo (b) PaRo (c) Leonardo (d) Probo (e) Kismet (f) iCat (g) Aibo (h) Geminoid (i) Furhat (j) Zeno (k) NAO (l) iCub

Figure 1: Examples of social robots.



(a) Pepper (b) Poppy (c) Nexi (d) Simon (e) Jibo (f) Buddy (g) Kuri (h) ElliQ (i) Travis (j) Vyo (k) AUR (l) Mechanical Ottoman

Figure 2: Examples of social robots (cont.).

2 SOCIAL ROBOTS

Social robots are designed to be able to express social behaviours to communicate with their users. Their designs vary greatly according to their roles, but also because of the aesthetic and technical choices of their designers. Examples of social robots are shown in figures 1 and 2. We class them along 3 dimensions: appearance, morphology and facial expressions implementation.

2.1 Appearance

Some designers choose to endow their robot with a human or humanoid form, with different degrees of realism. Geminoid (Nishio et al., 2007) and Furhat (Al Moubayed et al., 2012) are designed to get as close as possible to the human appearance, while Zeno (Hanson et al., 2009) takes inspiration from manga characters. Conversely, other robots such as Nexi (Fitzpatrick, 2012), iCub (Beira et al., 2006), Simon (Chao et al., 2010), Pepper[1], NAO (Gouaillier et al., 2009) and Poppy (Lapeyre et al., 2014) have forms inspired by humans but without aiming for realism.

The animal form is also widely used, sometimes inspired by imaginary animals. Pleo [2] takes the shape and appearance of a dinosaur while PaRo (Shibata et al., 1997) is inspired by a seal. Probo (Saldien et al., 2008), Leonardo (Brooks et al., 2004) or Kismet (Breazeal and Scassellati, 1999) have an animal-like appearance without one being able to define the animals they resemble. Finally, Aibo (Fujita, 2001)

[1] https://www.ald.softbankrobotics.com/en/robots/pepper/find-out-more-about-pepper

[2] http://www.pleoworld.com

or iCat (van Breemen et al., 2005) have a form inspired by animals that can be clearly defined but with a *cartoonish* appearance.

Other designers break free more or less strongly from human or animal forms and appearances. Some robots such as Buddy[3] or Kuri[4] retain a shape with a head and eyes. Others such as Jibo[5], Travis (Hoffman, 2012) or ElliQ[6] retain only a head-like shape. Finally, others such as the Vyo (Luria et al., 2016) abstracted even more strongly from animal forms by adopting a form closer to a household appliance. Despite this abstraction effort, its shape remains evocative of a head.

Finally, some designers uses furniture shape. For instance, AUR (Hoffman et al., 2007) takes the form of a lamp while the Mechanical Ottoman (Sirkin et al., 2015) is an actual footrest that has been robotized.

2.2 Morphology

Social robots can also be classified according to their morphology and more particularly their controllable morphology, thus ignoring the parts of their "body" that are only aesthetic. As we have seen for appearance, it can be difficult to avoid animal vocabulary to talk about the form of social robots. We will use this vocabulary for our morphology classification.

A first category groups together the *robotic heads*, which consist essentially of a head and neck. This category includes precursors such as Kismet or iCat, but also the more recent ones such as Furhat, Jibo or ElliQ and Vyo. Travis robot can also be classified in this category, although it has a mechanized foot and smartphone mount.

A second category includes *robotic torsos* equipped with a torso and arms. Probo, Leonardo and Geminoid robots are in this category. Some humanoid robots such as Zeno, Poppy or NAO also exist in "torso" versions restricted to the upper body.

Some robots can be classed as mobile variant of those two categories. Kuri and Buddy can thus be considered *mobile robotic heads*, while Nexi, Simon and Pepper can be considered *mobile robotic torso*, although they are most often defined as *wheeled humanoids*.

A final category includes robots with a complete "body", either bipedal like iCub, NAO, Poppy and Zeno, or quadruped like Aibo and Pleo.

[3] http://www.bluefrogrobotics.com/en/buddy/

[4] https://www.heykuri.com/explore-your-home-robot

[5] https://www.jibo.com/

[6] https://www.intuitionrobotics.com/elliq

2.3 Facial Expressions

The last axis to classify social robots is the choice of implementing facial expressions, given the importance of the face for a social robot. Some robots such as PaRo, Travis, ElliQ and Vyo have no facial expressions. NAO, Pepper and Aibo are also minimalist in this area as they have only a few LEDs that do not allow facial expressions to be represented as such. iCub is equipped with LED panels to define the shape of its eyebrows and mouth. Other robots like Jibo and Buddy use a screen for this purpose. Furhat also uses a screen but retro-projected on a face shape. Finally, some robots have an articulated face. It is the most represented category among the robots described above with Leonardo, Kismet, Probo, Zeno, Nexi, Simon and Geminoid.

3 EXPRESSIVE ROBOTS COMPONENTS

Our analysis of the different social robots reveals similarities in actuators used for expressive purposes. We define 4 categories of actuators: main and secondary motors (dynamic actuators), screens and LEDs (static actuators).

3.1 Dynamic Actuators

Main Motors. The main motors have as their primary role the movement of the robot joints. They most often have to be able to provide an important torque, so that they can move the attached parts of the robot. The motors of a humanoid robot's shoulder must therefore have enough torque to carry its arm, those of the elbow its forearm and those of the wrist only its hand. Their functional importance means that the vast majority of social robots are equipped with them. The range of Robotis Dynamixel motors presented in figure 3 is often used in the prototyping phase for this type of actuators.

Figure 3: Dynamixel servomotors line from Robotis.

Secondary Motors. Secondary motors have mainly an expressive function and are often used for the movements of the elements of robots face and hands. They generally do not need to provide a significant couple. In most cases, they do not need to be very precise either. Kismet (figure 4) is an example of a robot whose facial expressions are generated by 15 secondary motors. Radio-controlled vehicle actuators, sometimes called hobby servos, are generally used for this purpose during the prototyping phase. Figure 5 shows some examples of this type of motors.

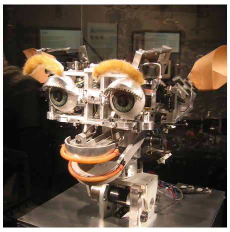


Figure 4: Kismet.

Figure 5: Examples of RC servomotors.

3.2 Static Actuators

Screens. In recent years, usage of screens as components of social robots has increased. Indeed, screens can represent facial expressions without the mechanical complexity that is required to generate facial expressions using motors. They also have the advantage of being very flexible and can display facial expressions, iconography or even more classic graphical user interfaces. In addition, the cost of screens has dropped sharply with the democratization of smartphones and tablets. The Jibo robot is probably the first robot to adopt the screen as its main actuator. Figure 6 illustrates the different types of uses of the Jibo screen. The Pepper robot also uses a screen, positioned on its chest in this case, whose main function is to display a graphical user interface but which is sometimes used for expressive purposes.

Figure 6: Different functions of Jibo's screen. From left to right, Jibo's screen is used to display the stream of a videoconference, a graphical user interface, an illustration of children's story, an icon indicating the current application, an icon expressing an emotion and a facial expression.

LEDs. LEDs are used as expressive actuators in two ways. The first is to use LEDs to represent anthropomorphic facial expressions. For example, the iCub robot is equipped with LED panels to define the shape of its eyebrows and mouth. The second is to use them to display a color representing an emotion or state of the robot. The Simon robot is equipped with ears illuminated by controllable LEDs. These two uses are not exclusive, the same LEDs can be used for both, as for the LEDs around the eyes of the NAO and Pepper robots, which are sometimes used to indicate an emotion by varying their color but also to represent a kind of blink of the eyes. LEDs can also be seen as very low-resolution displays.

4 OVERVIEW OF BLENDER FEATURES

The prototyping tool we present is based on Blender, a professional open-source 3D creation software. Blender's featureset is very broad, with features ranging from 3D modelling to video editing and animation. We will present the different feature that are proposed by Blender to animate 3D characters and the extension capabilities that it offers.

4.1 Defining Shapes

Geometric Modelling. Blender provides many tools to model objects or characters in 3D. The general principle is to model these forms as *meshes*. A mesh is an approximation of a surface by triangular or quadrilateral facets. Each face is defined by its vertices and edges. A shape is modeled by starting from a basic (or primitive) mesh and moving, dividing or removing its vertices, edges and faces, in order to sculpt it until the desired shape is obtained as shown in figure 7.

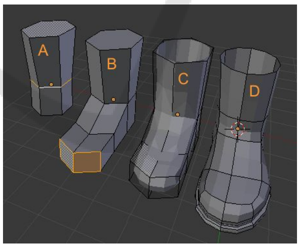


Figure 7: Modelling of a boot in Blender.

Figure 8: 12 examples of shape keys for Sintel's character.

Blend Shapes. In order to animate deformations of objects or characters, Blender provides shape interpolation features. This works by creating variants of the same mesh called *shape keys* and interpolating them with variable weights to obtain a *blend shape* of the different deformations. An important constraint is that these variants must retain the same vertices, edges and faces, because the mesh topology should to be identical in order to be able to interpolate them. This allows for example to have several variations of a character's face with different expressions and to animate its emotions by modulating the weights of these variants. Figure 8 shows examples of shape keys designed to animate the Sintel character in the eponymous animated short film of the Blender Foundation.

Shape Drivers. Controlling shape interpolation quickly becomes complicated by limiting itself to the shape keys weight interface. Blender allows you to create *drivers*, i. e. virtual objects whose position is associated with the weights of one or more shape keys. Animating these virtual objects then means animating the weights of the shape keys attached to them, thus animating the deformation of the shape itself. This feature allows animators to create their own graphical control interface to define a blend shape. Figure 9 shows an example of shape interpolation controlled through a shape driver.

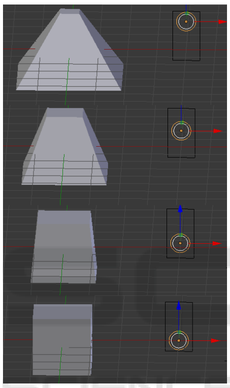


Figure 9: Example of a shape driver.

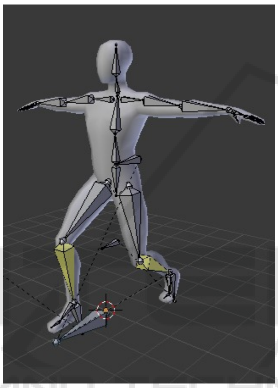


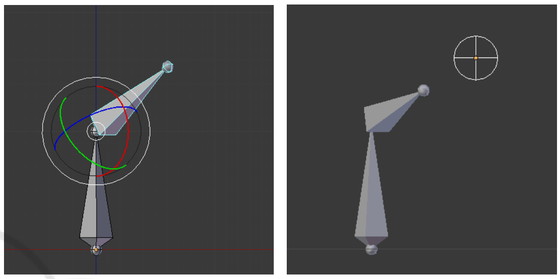
Figure 10: Example of an armature.

4.2 Defining Poses

Armatures are another means proposed by Blender to control the deformation of a mesh or set of meshes. A framework can be seen as the skeleton of a character. It is composed of one or more hierarchically organized *bones* to which meshes can be attached. The latter will then follow the movements and deformations of this bone. The movements and deformations of a bone can be constrained according to the desired movements of the character. A first constraint that may be desired is to force the bone to keep the same length, thus limiting its movements to a rotation. It may also be desired to freeze one or more rotations. An elbow bone could be forced to have only one degree of freedom. Finally, you may wish to limit the rotation over a given interval, thus defining a minimum angle and a maximum angle. An armature pose can be modified in two ways: by *forward kinematics* or by *inverse kinematics*.

Forward Kinematics. The forward kinematics method consists of directly modifying the angle between a bone and its parent. This method gives precise control but can quickly become tedious when the number of bones increases.

Inverse Kinematics. The inverse kinematics method involves defining targets that a bone will try to reach. Blender then uses an inverse kinematic engine to find the armature pose which minimizes the distance between the bone and the target while respecting the constraints of the armature.



(a) Forward kinematics (b) Inverse kinematics

Figure 11: Comparison of forward and inverse kinematics for defining an armature pose.

4.3 Keyframes Animation

Animation in Blender is based on the principle of keyframes. A keyframe is a record of the value of a parameter at a given point in an animation. In Blender, all parameters can be animated, such as the objects position, characters poses or the different shape keys' weights. To animate an action, the animator starts by defining keyframes of the animation by choosing the parameters to be recorded and when to do so. These keyframes can then be shifted in time on the *dope sheet* to fine-tune the animation timing. Finally, the speed profile of the transition from one keyframe to the next can be defined using the *F-curve editor*.

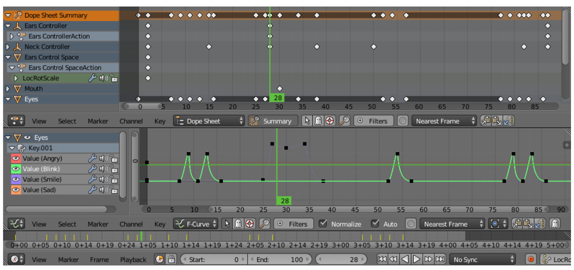


Figure 12: Keyframes animation interface in Blender. The top part shows the *dope-sheet* and the bottom part the *F-curve editor*.

4.4 Python API

Blender's features can be extended with the integrated Python interpreter. The API offers many possibilities. First, it provides reading and writing access to Blender's data structures, allowing for example to retrieve an object's position. It also allows to attach functions to Blender's event system. Finally, it allows to add elements to the Blender's user interface.

5 OVERVIEW OF OUR SYSTEM

We have previously presented the different categories of components commonly used for expressive purposes in Social Robotics, as well as Blender's various modeling, animation and extensibility features. Here we describe how we use Blender's features to implement an animation system for each component category.

5.1 Mapping Actuators to Blender's Features

The general principle of our system is to transpose the state of an animated virtual object in Blender to actuators on the real robot. The control of the different categories of actuators can be divided into two groups according to the principle of operation: motors animation and screens animation.

5.1.1 Motors Animation

Among Blender's features, we have introduced the *shapes drivers*, virtual objects whose positions drive shape keys' weights. Our system uses the driver concept to control the position of the main and secondary motors, i. e. the position or angle of an animated virtual object in Blender drives the angle of a physical motor. Two types of *motor drivers* can be used: armatures and control rigs.

Armatures. As we have seen before, the armatures allow Blender to define the skeleton of a character. In our case, they are a natural solution to control the robot's main motors. An armature can be defined in Blender to model the kinematic chain(s) of the robot, each bone representing a motor and its constraints, i. e. the axis of rotation and the minimum and maximum angle. Thanks to Blender's inverse kinematics features described above, it is also possible to define targets for certain armature bones. This allows to control its pose by directly manipulating these targets. For instance, mapping the `x` angle of the `l_elbow` bone and a main motor (Dynamixel) of id `12` is done by adding these few lines to the mapping file:

```
{
    'from': {
        'path': 'l_elbow/angle/x',
        'min':  0,
        'max':  90
    },
    'to': {
        'path': 'Dynamixel/12',
        'min':  -90,
        'max':  0
    }
}
```

Allowing a transformation between the bone and the motor angles allows more flexibility in setting up the mapping. We choose to use a linear transformation from the bone angle range to the motor angle range, defined by their respective minimum and maximum angles. This method of configuring the mapping is intuitive as it is easy to find those minimum and maximum angles and to visualize the linear transformation.

Control Rig. We have previously presented Blender's features to enable the user to define a custom graphical interface also called *control rig* for controlling the weights of different shape keys. Similarly, our system allows to retrieve a virtual object *position* to control a motor angle. For example, the animator can create a *slider* by defining a virtual object constrainted on a given range on the `x` axis and fixed on the `y` and `z` axis. Control rigs are useful for controlling secondary motors. For example, mapping the `x` position of a virtual objet `ears_slider` and a secondary motor (or hobby) of id `6` is done by adding these few lines to the mapping file:

```
{
    'from': {
        'path': 'ears_slider/position/x',
        'min': 0,
        'max': 90
    },
    'to': {
        'path': 'Hobby/6',
        'min': 0,
        'max': 90
    }
}
```

5.1.2 Screens Animation

In our system, we use smartphone or tablet as off-the-shelf screens. We render the meshes that would be captured by a Blender virtual camera on the smartphone or tablet. This allows the animator to use all modeling and shape interpolation features provided by Blender to animate facial expressions, iconography or text. Mapping the virtual camera `face_camera` and the screen of id `1` correspond to adding these line to the mapping file:

```
{
    'from': {
        'path': 'face_camera'
    },
    'to': {
        'path': 'Screen/1'
    }
}
```

5.2 Architecture

Figure 13 presents the architecture of our system implementing the synchronization of each actuator with the corresponding virtual object animated in Blender. The architecture can be broken down into two parts: the *dispatcher* that communicates with Blender, and the controllers that communicate with the actuators.

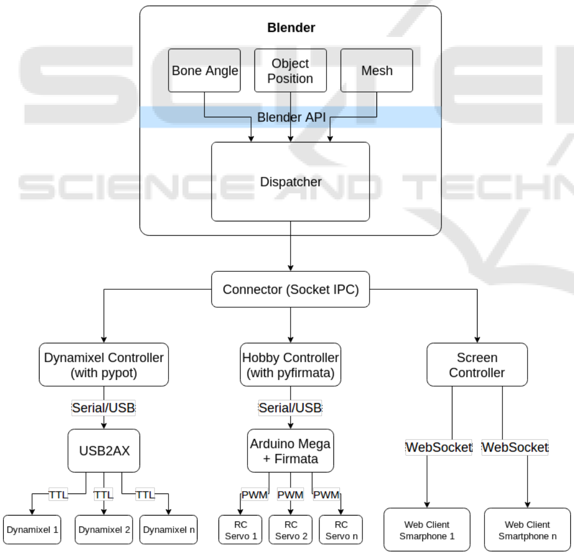


Figure 13: Diagram of our system architecture.

5.2.1 Dispatcher

The *dispatcher* is the main component of our system. Its operation is controlled by the *mapping file* described above which defines the associations between virtual objects and actuators. Virtual objects and actuators are represented by an address. The source address contains the name of the virtual object and the attribute of interest. The destination address is the name of the controller that should receive the information followed by an actuator identifier. The association can also contain a transformation to be made on the value of the attribute before sending it to the controller.

The *dispatcher* is plugged into Blender's event system by attaching itself as a callback function to the `scene_update_post` event. Each time Blender updates, the *dispatcher* checks whether the virtual scene has been modified, i. e. whether a virtual object has been moved, either by the user or by Blender's animation engine.

If so, the *dispatcher* processes each association defined in the *mapping file*: it retrieves the information defined by the source address and transmits it to the controller indicated by the destination address, along with the destination actuator identifier. If the source virtual object is a camera, the transmitted information contains the camera settings and the scene meshes. Otherwise, it contains the value of the attribute of interest as defined in the source address.

5.2.2 Controllers

A controller operates all actuators of the same type. Those actuators are differentiated within one controller by a unique identifier. These are the identifiers that can be found in the destination addresses of the mapping file. Controllers are independent processes with which the *dispatcher* communicates asynchronously through an inter-process communication socket that we will call the *connector*. We use the implementation of the *Publish-Subscribe* communication pattern of the *ZeroMQ* library. The controller name contained in the destination address corresponds to the subtopic *topic* on which the information will be published by the *dispatcher*. This choice of architecture allows new actuators to be integrated into the system by adding controllers. All you need to do is choose a *topic* identifier and use it in a destination address. The new controller will then only have to subscribe to the *topic* to join the system.

For example, to add LEDs control to the system, we could use the fact that LEDs and especially LED panels can be thought of as low resolution screens. First, we would need to create an association between a virtual camera and a destination address beginning with the topic `LED` by adding the following lines to the *mapping file*:

```
{
    'from': {
        'path': 'leds_camera'
    },
    'to': {
        'path': 'LED/1'
    }
}
```

We would then be able to subscribe a LED controller to the `LED` topic through the socket *connector*.

In our implementation, subscription has the particularity of being "lazy", i. e. it corresponds to retrieving only the last message published on the *topic*. In this way, the latest information can be used to limit latency between Blender and actuators. This is possible because we chose to directly send absolute values from Blender to the controllers and to control the motors in position.

The system integrates 3 controllers: `Dynamixel` for Robotis Dynamixel motors, `Hobby` for RC servo motors and `Screen` for screens.

`Dynamixel` Controller. Robotis Dynamixel motors are often used in social robotics during the prototyping phase. They are digital actuators with TTL half-duplex interface. We use a *USB2AX* board and the *PyPot* library developed as part of the Poppy project (Lapeyre et al., 2014) to control the motors.

`Hobby` Controller. RC servomotors must be controlled by a PWM signal (for *Pulse Width Modulation*) encoding a target angle. We use an *Arduino MEGA* board to generate this signal using the *Servo* library included in the standard Arduino distribution. In order to directly control the signal generated by the board from the controller written in Python, we use *firmata* on the Arduino, a firmware allowing to control the features of the board remotely, and the library *pyfirmata* on the Python side. The communication between the Arduino board and the controller is done via a USB connection.

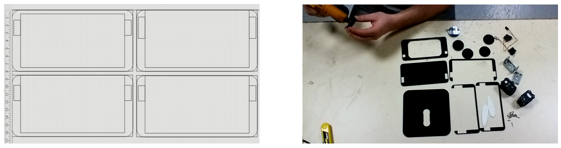
`Screen` Controller. We use Android smartphones as screens (and potentially tablets). They run a web application connected to the `Screen` controller via *WebSocket*. This application is responsible for rendering the scene 3D thanks to the camera parameters and the scene meshes transmitted by the controller. It uses the library *Three.js*, a *Javascript* library to create and render 3D scenes thanks to the *WebGL* API. The rendering is therefore not done by Blender but directly by the browser on the phone.

6 CASE STUDIES

In order to experiment and validate this prototyping system of animated robots, we applied it to the animation of two examples of social robots: Mia, a robot we designed specifically for this purpose, and Poppy, an existing open-source robot.

6.1 Mia

We designed the Mia robot as an example of the developed system (figure 14). It is equipped with 3 types of actuators that we have identified as frequently used in social robotics, i. e. main motors, secondary motors and screens.



(a) Screenshot of Mia's structure design.

(b) Screenshot of Mia's assembly (in a plexiglass version).

Figure 14: Design and assembly of Mia.

Mia has 4 degrees of freedom, 2 main motors for the neck and 1 secondary motor per ear. The neck is powered by Robotis Dynamixel *AX12A* servomotors while each ear uses a RC servomotor. The structure is designed from parts included with the Dynamixel motors and parts laser cut in wood fibreboard panels (MDF). On Blender's side, the 2 Dynamixel actuators are controlled by an armature which takes up the geometric structure of the neck and the 2 RC servomotors of its ears are controlled by a 2D slider (figure 16).

Mia also comes with a screen displaying 2 eyes and a mouth. The eyes are blend shapes of the initial eye shape and 4 shape keys (figure 17) whose weights are controlled in Blender thanks to 4 sliders.

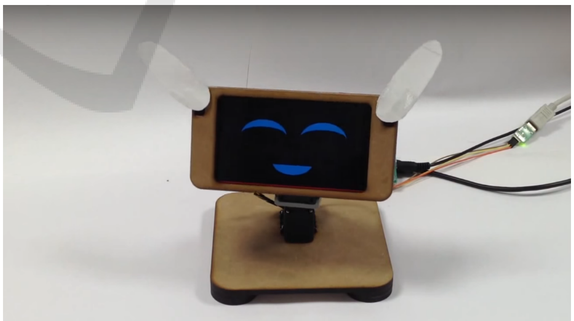


Figure 15: Mia presentation.

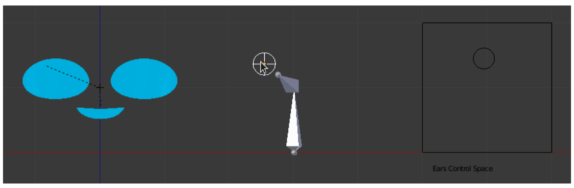


Figure 16: Mia control rig.

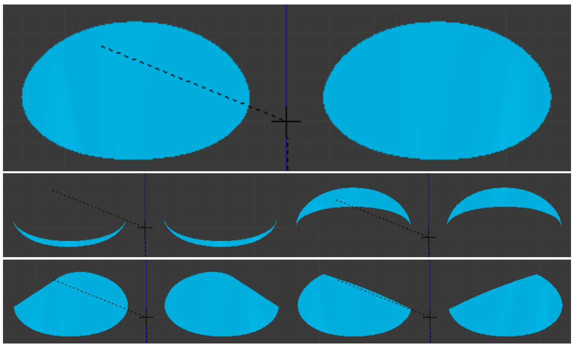


Figure 17: Basic shape (top) and shape keys (bottom) for Mia eyes.

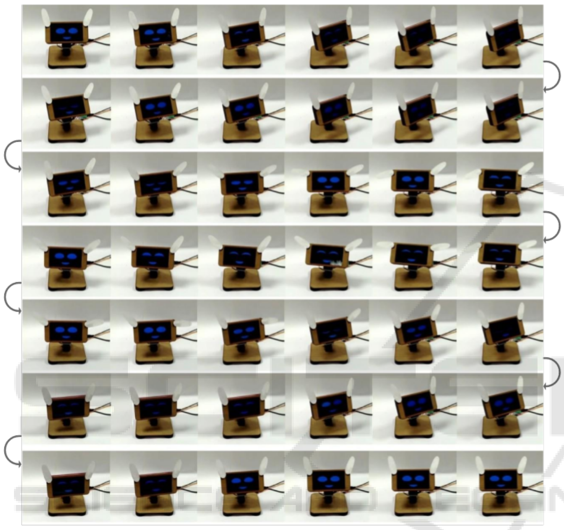


Figure 18: Example animation of Mia. The corresponding video is available at the following address: https://youtu.be/aQ-g0b3mRRo.

Observations and Discussion

Mia can easily be animated with this system. The physical robot allows an immediate feedback. The movement is performed with all the speed or acceleration constraints of the robot as well as the motor generated sound. This feedback makes it possible to quickly judge the final result, and in particular to verify that the movement keeps the desired style.

6.2 Poppy

Poppy is an open-source robot (Lapeyre et al., 2014) developped by the Flowers team at Inria Bordeaux. Initially designed as an experimental platform to study the acquisition of walking by children, it has since then been used in multiple artistic performances, as educational platform or as compagnon robot for hospitalized children.

Figure 19: Poppy Torso presentation.

We use Poppy *torso* version. It has 13 degrees of freedom: 2 for the neck, 3 for the bust and 4 for each arm. These are all powered by Robotis Dynamixel *MX28AT* servomotors, except for the neck which uses *AX12A* servomotors from the same line. On Blender's side, the robot motors are controlled by an armature that takes up the geometrical structure of the real robot.

Observations and Discussion

Although Poppy can be animated thanks to this system, new difficulties are encountered due to the high number of degrees of freedom of the robot. First, inverse kinematics must be used to define the robot's pose, directly controlling the angles becoming tedious. The robot could potentially be used as a tangible interface to directly define the robot pose instead of relying on inverse kinematics. Secondly, the virtual robot must be handled with care to avoid self-collisions on the real robot. A collision detection mechanism could avoid putting this task and the associated cognitive burden on the user.

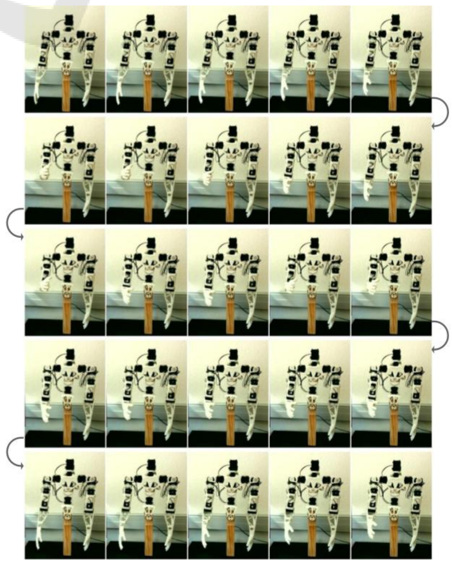


Figure 20: Example animation of the Poppy robot.

7 CONCLUSIONS

The PEAR framework presented in this paper aims to respond to the rising need for prototyping and design tools associated with the emergence of the social robots market. We showed that existing social robots share common basic components and how those components can be animated using 3D animation tools and methods. This enables the rapid prototyping of expressive animated robots as we have shown with the prototyping of the Mia robot. We also showed how this framework can be used to easily create an animation tool for an existing robot, using Poppy as an example.

Case studies also raised some limitations of the current system. Animating a robot by mapping the state of virtual objects onto its actuators works very well for simple robots like Mia, with few degrees of freedom and no possibilities of self-collision. However, more complex robots like Poppy would benefit from features managing the robot physical constraints for the user. (Nakaoka, 2012) showed for example an animation tool integrating an automated balancing of the robot. Our system could also be improved through better input modalities. In our previous work (Balit et al., 2016), we showed how a robot can be used as a tangible interface for defining poses, thus avoinding the reliance on inverse kinematics. We are looking into ways of integrating those features to the presented system.

We believe that fostering a design community will be essential for the developpement of social robots. Having a common prototyping tool would be an important step in this direction. 3D animation tools have large communities of animators and character designers whose skills could grealty improve the user experience of social robots. Our work extending a 3D animation tools for robot prototyping is a first step towards building a bridge between those artists and social robots design.

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