Assisting Storyboarders in Expressive 3D Pose Creation with a 2D Sketch-based Interface

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Abstract: Storyboarding is an ideation and prototyping process that constitutes one of the keystones in visual and narrative productions, such as filmmaking and performing arts. During this step, storyboard artists start giving poses and expressions to their characters. However, in the case of 3D film making, the final movie will be transposed from a 2D to a 3D medium, which means that artists do not have an accurate view of the result of their work. Existing 3D interfaces do not suit the storyboarders' needs, as their complexity tend to impede and alter their creative process. This study focus on the development of an intuitive system that allows artists to pose 3D characters using simple 2D strokes as an interaction method. Our technique combines several representation modes to let users incrementally develop their poses in a monocular view. We evaluated the system by posing various characters with different anatomies and levels of details, which showed that it has the advantage of being flexible and helps in gaining time compared to the classical keyframe method.

1 INTRODUCTION

As a powerful narrative tool, the storyboard depicts the story's actions, rhythm and emotions by offering the first visual aspect of the movie. One of the main tasks entrusted to storyboarders is the character staging, acting and the creation of expressions. The majority of existing storyboard tools provide a 2D sketching interface, as it allows artists to freely and intuitively experiment aesthetic and narrative options by creating expressive visuals. However, these tools thoroughly ignore the 3D nature of the final work. As a consequence, a gap appears between the 2D and 3D media, which generates inaccuracies during the transition between these steps. Not being able to see any 3D feedback prevents the director from checking if the narrative and visual ideas put in the storyboard panels will effectively work when transposed into a 3D environment.

If sketching tools are intuitive, 3D techniques remain complex and laborious, especially for non expert users. In the case of keyframe animation, the user must manipulate 3D controllers and several parameters, which is quite unnatural. These constraints would burden and slacken traditional artists and negatively interfere with their creative process.

The main goal of this study is to facilitate the transition between preproduction and production in the case of character posing. To do so, we developed a 3D posing method that exclusively relies on 2D sketch gestures. Users are inserted into a feedback loop where they can operate with three representation modes to build a 3D pose. This system offers an intuitive interface that allows artists to quickly pose 3D characters in a fixed 2D panel, respecting the main constraints of the storyboarders. We begin this paper by exploring the representation methods established by previous research on the subject. Then, we define the challenges that are specific to the field of storyboarding and we describe the implementation of our method. Finally, we analyze the results and describe the improvements to be made in our future works.

2 BACKGROUND

2.1 Abstractions

Poses can be depicted by artists using several representation methods that we will call abstractions here, as you can see in figure 1.

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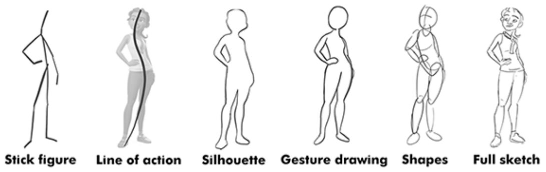


Figure 1: Examples of abstractions that can be interpreted by sketch posing methods.

2.1.1 Stick Figure

The vast majority of the sketch posing interfaces require stick figures as input. Some of them add an automatic size correction feature, like in (Lin et al., 2012)'s research. In other methods, stick figures can be sketched in a totally free-form way, like in (Choi et al., 2012) and (Mao et al., 2006)'s works. Stick figures have the advantages of being close to the real structure of the 3D skeleton, which makes them easier to parse and to interpret foreshortening effects. The main drawbacks when using stick figures are that they imply symmetry ambiguities and don't provide any volume hint, nor twist information.

2.1.2 Line of Action

(Guay, 2015) uses abstraction concepts inspired by traditional artists and animators, such as the line of action, which is a simple unique curve that indicates the global stream and dynamic of the pose. Other systems have integrated this concept to posing operations such as (Mahmudi et al., 2016), (Low, 2014) and (Öztireli et al., 2013). The line of action abstraction is intuitive, expressive and quick to produce as it doesn't involve the process of fully sketching the character. That makes it particularly suited for incremental processes. However, depth, volume and twist information can be difficult to interpret directly.

2.1.3 Silhouette

Outline or silhouette representations have the benefit of helping in the definition of global shapes and determining the area an element should take on screen. But they tend to be less intuitive to draw for artists and hard to parse, as they don't clearly depict the different body elements and produce symmetry ambiguities. This kind of representation is more suited for procedurally driven parts such as hair, as we can see in (Seki and Igarashi, 2017)'s study.

2.1.4 Gesture Drawing

(Bessmeltsev et al., 2016) developed an interface that uses gesture drawings as input, which are intuitive and suggestive sketches representing a pose in the least ambiguous way. Gesture drawings are less technical than stick figures, more natural than outlines and less abstract and ambiguous than lines of action. However, unlike these simple abstractions, they need a complex calculation step to parse the input sketches, which make it difficult to use in real time.

2.1.5 Shape Decomposition

Characters can also be constructed by dividing their parts into several shapes, such as squares or spheres, like in (Thorne and Burke, 2004)'s system. (Hahn et al., 2015) also uses decomposed outlines to represent body parts.

2.2 Data Requirements

Sketch posing methods can rely on existing motion databases, like in (Jain et al., 2009) or (Lin, 2006) technique. Other research also exploit comparisons between drawings from users and rendered poses from databases, such as (Lv et al., 2015) and (Wei and Chai, 2011). Sketches can be used as queries to retrieve poses in a large database, like (Choi et al., 2012) and (Xiao et al., 2015) research. More recently, learning algorithms have been developed to recognize or reconstruct 3D poses from sketches using datasets, like in (Akman et al., 2020). We can also note techniques that require user annotations to specify joints positions, such as in (Gouvatsos, 2018) .

3 CHALLENGES

Storyboard drawings hold specificities that must be taken into account when building sketch posing systems, as they are usually rough and simplified.

Firstly, our tool should minimize the most tedious and least artistic tasks to let the user focus more on an aesthetic and narrative works. Therefore, it has to be fully automated: we do not want to impose any labeling step to the user.

Storyboard poses tend to be expressive: artists use exaggerations and emphasis, such as stretch and squash deformations, to enhance an emotion, which may create flawed proportions. It should be taken into account when analyzing sketches.

Our storyboarding system must handle depth ambiguities, in the most plausible way: given a 2D projection, several 3D solutions could correspond to the same 2D representation.

Moreover, we want to integrate the artist into a retroactive feedback loop with the digital tool. Thus, the algorithms must be fast enough to offer a 3D feedback in real time. To let the user refine his work progressively, the workflow has to remain incremental.

In addition, we don't want to confuse, disturb or slow down the storyboarder while conceiving the panels. Sketching should be the unique interaction mode. No 3D operations should be needed to pose the character. As a consequence, the system has to stay monocular: artists should be able to create the pose exclusively into their frame view.

Finally, we want the tool to be usable by any kind of animation production team and for any type of project. As a consequence, the algorithm should not be based on any pose or motion database, which tends to be limited to realistic bipedal characters.

4 OVERVIEW

In our sketch posing method, we provide a combination of sketching tools the storyboarder can employ according to his needs. The majority of the interactions with the system are done by sketching. During the session, the artist is always included in a retroactive feedback loop, as all of his actions are immediately applied to the 3D scene and displayed in the viewport. The user interface is visible in figure 3-A.

5 IMPLEMENTATION

5.1 Architecture

Our sketch posing tool is divided in two sections, as you can see in figure 2. The first one is the core system: it contains several modules that are necessary for the pose computation. The abstraction modules define useful objects that will be exploited during the pose estimation stage, such as the camera, the stroke and the 3D object armature. The posing modules hold the three posing tools: global posing, line posing and the sphere manipulator, their algorithms will be described in 5.3, 5.4 and 5.5. These tools need the user settings and geometry modules to perform calculations. The output data of the core system depends on the posing tool selected, it can be positions or rotations to update in the scene, with a reference to the labels of the armature elements to edit.

5.2 Scene Data Management

The first step in our sketch posing system consists in gathering all the required data from the storyboard

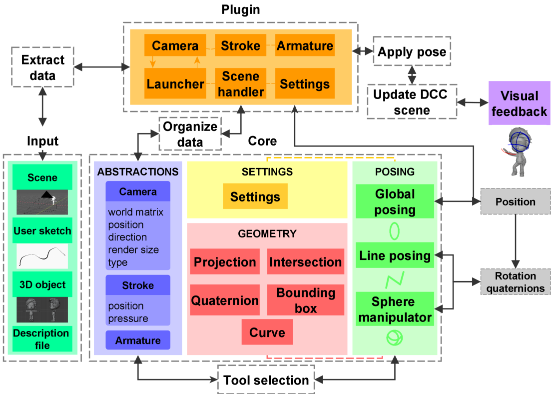


Figure 2: Sketch posing system architecture and modules.

scene and organize them in order to ease the pose calculation. The plugin part of our system extracts required data from a digital content creation tool, and the core part structures it to handle pose estimation.

Our system assumes the 3D camera has already been placed in the 3D scene. Thus, the framework takes several camera parameters as input, such as the normalized world transformation matrix and the direction vector.

The second data type we must handle is the 2D sketch stroke. A stroke is a curve formed by a set of ordered points, usually created with a graphic pen tablet. In our system, strokes are drawn on a 2D plane that is parallel to the camera clipping planes. We extract the position of each stroke point in the world space coordinate system, as well as the pen pressure values.

Regarding the character skeleton, we made the choice to take joints positions and bones labels as input rig data to our system. Bones are segments that connect a first joint (head joint) to a terminal joint (tail joint). They can be rotated by taking the tail joint as the center of rotation. Joints are the smallest rig elements and represent the point at which bones are connected.

5.3 Line Posing

The line posing tool allows artists to set up a character pose by sketching strokes onto a 3D rigged object. In our system, the bone length remains constant and the first joint of the chain is never moved. Line posing operations consist in selecting the right bone chain to edit, analyze the curve to identify its type and parse it to extract landmark points. Then, the tool replaces the joints in 3D space and computes new bone rotations. The plugin picks this data and applies it to the armature in the 3D viewport. The following sections describe the process of line posing.

5.3.1 Body Part Selection

The first step of our line posing process consists in identifying the body part to edit. For now, we decided to define the editable chain according to its proximity to the user stroke. To do so, we transpose the stroke points and each chain's first joint to screen coordinates. Then, we select the chain for which its top joint is the closest to the first stroke point. Finally, the stroke is translated to make its first point lie onto the chain's first joint in the camera view.

5.3.2 Stroke Type Analysis

The tool must be able to handle various stroke styles. According to his needs, the user can trace stiff angular lines, which can be similar to the kind of lines we find in stick figures. These curves usually have several marked turning points, which are clues that can be used to identify joint positions. The second type of shape handled by our line posing tool gathers smoother and more supple lines that do not have marked turning points. They are generally used by artists to indicate slighter and more subtle intentions in body pose.

Both types of line are represented in figure 3-B and must be parsed differently to make the posing system more accurate. However, we think the user shouldn't have to manually activate parameters in the interface to indicate the kind of stroke he intends to draw. As a consequence, we first analyze the input curve to automatically identify the curve type we will have to process.

To do so, we use the sinuosity index theorized by (Mueller,). We compare the result with an arbitrary threshold value ε as illustrated in the inequation 1.

$$\frac{\sum_{i=0}^{n-1} \|\overrightarrow{S_i S_{i+1}}\|}{\|\overrightarrow{S_0 S_n}\|} > 1 - \varepsilon \qquad (1)$$

If the ratio is superior to the threshold value, the stroke will be parsed as an angular stroke. By default, we set the threshold value as 0.05.

5.3.3 Joint Landmark Detection and Replacement

Parsing Angular Lines and Replacing Joints. The system starts by looking for landmarks, which are points on the 2D stroke that match with the chain joints. Those points are extracted using a variant of the Ramer Douglas Peucker algorithm (Douglas and Peucker, 1973) that takes the number of required points as input, which corresponds here to the number of joints.

Once the landmark points have been extracted, we must inversely project them in the 3D world space and determine each joint's new position. For all of the landmark points, we compute their depth order (see 5.3.4). Then, for each bone in the chain, we build a sphere with the bone head joint in worldspace coordinates J_j^{ws} as center and the bone length Bl_j as radius. We also build the segment from the camera position C_{pos}^{ws} to the tail joint's matching landmark point on the stroke L_{j+1}^{ws}. Next, we compute the intersection point I_{j+1}^{ws} between the line and the sphere to get the current bone's tail joint J_{j+1}^{ws} new position in world space. If several points have been found, we use the depth mask computed previously to select the nearest or farthest point from the camera. A representation of this process can be viewed in figure 3-C for the first iteration.

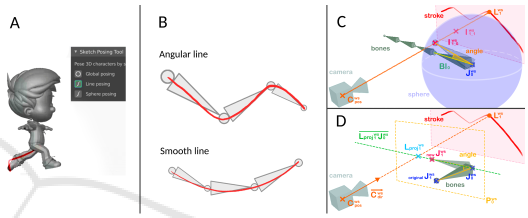


Figure 3: User interface screenshot (A). Line types (B). Angular line joint repositioning process and bone angle computation at iteration 0 (C). Bone rotation computation when parallel to the camera clipping plane (D).

If no intersection point could be found, which means that the segment between the landmarks is longer than the bone, we consider that the bone is parallel to the camera clipping plane. In that case, the system looks for the projection of the tail joint's matching landmark point $Lproj_{j+1}^{ws}$ from the camera position on the plane that is normal to the camera direction $\overrightarrow{C_{dir}^{ws}}$ and passing by the current head joint J_j^{ws}. Then, we search for the point on the line $\overline{J_j^{ws} Lproj_{j+1}^{ws}}$ that is at the Bl_j distance from the head joint. The tail joint position J_{j+1}^{ws} is updated with this new position, as described in figure 3-D. To handle cases where the represented bone segment is too long, two modes are available: by default, the system sticks to the landmark positions. Otherwise, if we want the next joints in the chain to be adjusted to preserve the global shape of the stroke, we compute the difference from the original landmark position L_{j+1}^{ss} to the new tail joint position J_{j+1}^{ss} in screen space coordinates. Then, we update the following landmarks in the list L^{ss} by subtracting their position with the computed difference, and we set their new world space position L^{ws} accordingly. We continue the iterations until the last joint of the chain has been replaced.

Parsing Smooth Lines and Replacing Joints. The first step, described in figure 4, consists in finding the new position of the last chain joint J_m^{ws} in worldspace coordinates according to the last stroke point S_n. We compute the intersection point I_m^{ws} between the line from the camera position C_{pos}^{ws} to the last stroke point S_n^{ws} with the sphere that has the first chain joint J_0^{ws} as center and the chain total cumulative bone length Cl as radius. If an intersection point is detected, we replace the last joint position with it.

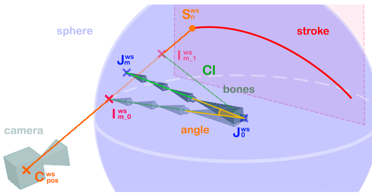


Figure 4: Calculation and replacement of the last joint of the chain if the bone is foreshortened.

Else, we consider that the chain is parallel to the camera clipping plane. The stroke points are projected on the plane P_0^{ws} that is normal to the camera direction and passing by the first joint J_0^{ws}. We have to find the intersection point between the bone chain and the projected stroke $Sproj^{ws}$ by maximizing its length. To do so, for each projected stroke segment $\overline{Sproj_i^{ws}Sproj_{i+1}^{ws}}$, we compute the intersection point between the current segment and the circle that has the first joint J_0^{ws} as center and the chain length Cl as radius, lying on P_0^{ws}. We update the position of the last joint J_m^{ws} to the first intersection point found (figure 5-A).

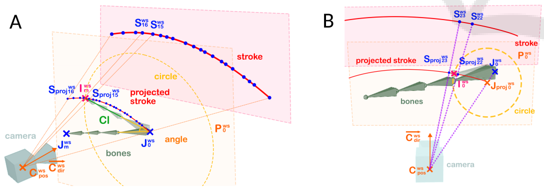


Figure 5: Replacement of the last joint of the chain if it is parallel to the camera clipping plane (A). Replacement of the bone chain to match the stroke shape at iteration 0 (B).

Then, each intermediate joint J_j^{ws} in the chain is replaced on the line from the first to the last joint $\overline{J_0^{ws}J_m^{ws}}$ with respect to each original bone length Bl_j.

Lastly, we determine the final position of the intermediate joints to make them consistent with the input curve (figure 5-B). For each bone in the chain, the system computes a projection point $Jproj_j^{ws}$ of the bone head joint J_j^{ws} on the plane P_j^{ws} that is normal to the camera direction and passing by the bone tail joint J_{j+1}^{ws}. Thereafter, for each stroke segment S_i^{ws}, we project its terminals onto P_j^{ws}. We look for an intersection point between the projected segment $\overline{Sproj_i^{ws}Sproj_{i+1}^{ws}}$ and the circle $Circle_j^{ws}$ constructed using the projected joint $Jproj_j^{ws}$ as center and the distance $Jproj_j^{ws}J_{j+1}^{ws}$ from the projected head joint to the tail joint as radius. For each potential intersection point I_k^{ws}, we compute the ratio r_j between the distance $Sproj_i^{ws}I_k^{ws}$ from the stroke segment's first point to this point and the distance $Sproj_i^{ws}Sproj_{i+1}^{ws}$ from the stroke segment's first point to its last point. If several intersection points have been found, we take the point that is associated with the highest ratio r_{max}. Finally, we assign this point position value to the current tail joint J_{j+1}^{ws} position.

5.3.4 Depth Order

As described in the background section 2, by using the bone's real length and the parsed stroke segment's length, we can compute the joints' depth values. However, if the bone is not normal or parallel to the camera plane, two solution points are available for the tail joint: the bone can point towards the camera or in the opposite direction. To resolve this ambiguity, we decided to establish the depth specification in the artist's workflow. As it has already been done in (Thorne and Burke, 2004)'s work, we took inspiration from traditional artists who tend to represent closer elements with thicker lines. Thus, the user can indicate the proximity of an element to the camera using pen pressure. In our algorithm, we first extract the pressure value P_i for each individual point S_i on the stroke. Then, for each stroke part between two landmark points L_j and L_{j+1}, we compute the local pressure mean $pmean_j$ of the intermediate stroke points. Next, we remap the mean $rmean_j$ from 0 to 1 using the maximum and minimum global pressure values $pmin_j$ and $pmax_j$, as you can see in the equation 2. In our system, a pressure threshold α which defaults to 0.5 is compared with the remapped mean. If the remapped mean is higher than α, the bone will be considered pointing forward to the camera. Otherwise, we will assume it points backwards. The comparison values for each bone are stored in a boolean array to be reused during the joint computation stage.

$$rmean_j = remap\left(\frac{\sum_{i=i_{start}}^{i_{end}-1} P_i}{i_{end} - i_{start}}, pmin_j, pmax_j, 0, 1\right) \quad (2)$$

5.3.5 Bones Rotations

We use the original and the computed joint position differences to process each bone rotation. Rotation values are encoded in quaternions to improve the algorithm efficiency, and are sent back to the digital creation tool to offer visual feedback to the user.

5.4 Sphere Manipulator

The sphere manipulator is constructed of three different strokes: one circle stroke Rs that indicates the body part to edit and two crossing curved strokes X_s^1 and X_s^2 that show the rotation direction.

5.4.1 Body Part Selection

To select the right chain to edit, we use the same method as in 5.3.1, but we use the center of the bounding box of the circle stroke in world space Rs_{center}^{ws} and the center of the bounding box of each editable bone chain Ch_{center}^{ws} instead.

5.4.2 Rotation Computation

Once the right bone chain has been selected, we must estimate the required bone rotation according to the user input sketches. First, we correct the position of the sphere manipulator by translating the three strokes to make the circle bounding box center Rs_{center}^{ws} overlap the selected chain bounding box center Ch_{center}^{ws}. We also compute the intersection point Xi^{ws} between the two cross strokes X_s^1 and X_s^2. Then, we calculate the intersection points L_k^{ws} between the line from the camera position to the cross point $\overline{C_{pos}^{ws} Xi^{ws}}$ and the sphere S with the bone chain bounding box center Ch_{center}^{ws} as center and the chain length Cl as diameter. We do the same operation to find the intersection points M_k^{ws} of the line from the camera to the bone bounding box center $\overline{C_{pos}^{ws} Ch_{center}^{ws}}$ with the previous sphere S. For now, we select by default the intersection point M^{ws} that is the closest to the camera. The desired rotation is represented by the angle between the vector $\overrightarrow{M_0^{ws} Ch_{center}^{ws}}$ going from the intersection point of the chain bounding box center to the chain bounding box center and the vector $\overrightarrow{L_0^{ws} Ch_{center}^{ws}}$ that goes from the intersection point to the chain's bounding box center. This process is illustrated in figure 6.

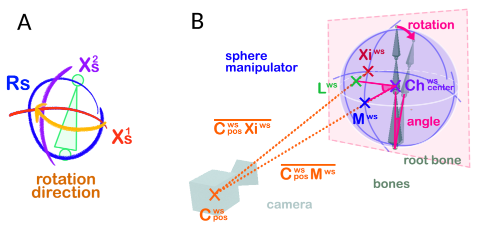


Figure 6: Sphere manipulator description (A). Computation of the bone chain rotation (B).

Using these two vectors, we are able to build a quaternion representing the required rotation. This rotation is applied back to the root bone of the chain.

5.5 Global Posing

With the global posing tool, artists can set the object's global position by drawing the area it should occupy on the 2D screen. To do so, we compute the accurate depth of the 3D character according to the size of the stroke in screen space and the real character size in world space.

The algorithm extracts the 3D object and the 2D stroke bounding boxes. Then, it builds a first bounding box vector $\overrightarrow{Obj_{bb}^{cs}}$ for the 3D object and a second one for the stroke $\overrightarrow{S_{bb}^{cs}}$ in camera space coordinates. Several modes are available to build the bounding box vectors: height, width and full. For example, in height mode, we only take the vector from the lowest $(0, y_{min}, 0)$ to the highest bounding box point $(0, y_{max}, 0)$. In width mode, we construct the vector with the leftmost $(x_{min}, 0, 0)$ and the rightmost $(x_{max}, 0, 0)$ points. By default, we select the vector from the left bottom shallowest point $(x_{min}, y_{min}, z_{min})$ to the right top deepest $(x_{max}, y_{max}, z_{max})$ point of the bounding box. Modes can be specified for each character in its JSON description file. According to the input 3D model, some modes can be more relevant than others. For example, if the model is particularly tall and thin, it could be more useful to only take into consideration the bounding box's height to compute the matching depth. On the other hand, if the character is significantly longer on the x axis, like the whale in figure 8, we should use the width mode to make the computation more accurate.

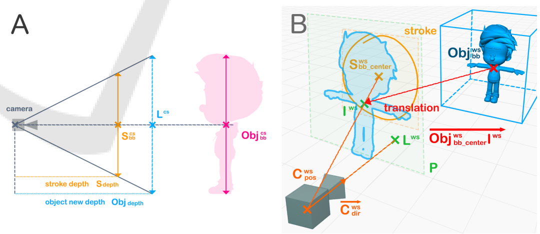
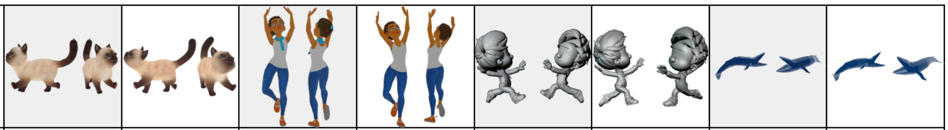


Figure 7: Computation of the depth of the character in camera space (A). Computation of the final position of the character and its translation vector (B).

We compute the depth of the character in camera space $Char_{depth}^{cs}$ by using basic projection rules (figure 7-A). We multiply the norm of the character bounding box vector $\overrightarrow{Obj_{bb}^{cs}}$ by the depth of the stroke object in camera space S_{depth}^{cs}. Then, we divide the result by the norm of the stroke bounding box vector $\overrightarrow{S_{bb}^{cs}}$.

$$Char_{depth}^{cs} = \frac{\|\overrightarrow{Obj_{bb}^{cs}}\| * S_{depth}^{cs}}{\|\overrightarrow{S_{bb}^{cs}}\|} \quad (3)$$

The system builds a camera centered landmark



Pose								
Method	Rig controllers	Our method	Rig controllers	Our method	Rig controllers	Our method	Rig controllers	Our method
Time	85s	28s	296s	62s	138s	50s	21s	6s
Manipulations	17	8	42	13	24	12	5	2
View changes	8	0	25	0	13	0	3	0

Figure 8: Comparaison of our posing method with the classical IK-FK method on pose creation tasks. The table surveys the time required to create the pose, the number of manipulations required and the number of camera angle changes.

point $L^{cs}(0,0,Char^{cs}_{depth})$ with the previously computed depth. The point is transposed into world space coordinates L^{ws}. To find the final position of the 3D object, we compute the intersection point I^{ws} between the line $\overline{C^{ws}_{pos}S^{ws}_{bb\_center}}$ from the camera position to the bounding box center of the stroke with the plane parallel to the camera clipping plane passing by the transposed landmark point L^{ws}. The translation vector comes from the current bounding box center to the intersection point $\overrightarrow{Obj^{ws}_{bb\_center}I^{ws}}$. This translation is applied to the 3D object in the digital content creation tool (figure 7-B).

6 RESULTS AND APPLICATIONS

Our system was integrated into Blender and tested using a pen tablet on 4 characters (figure 8). We created the same poses using the classical method with inverse and forward kinematic controllers and with our sketch posing method. The goal was to evaluate the benefits and the flaws of our technique. We have surveyed the time required to create the pose as well as the number of manipulations on the character and the changes of the view angle.

The results showed that our system needs less user interventions: 12 with our method versus 24 with the classical method on the third pose. It also requires less time to create the pose: 6 seconds versus 21 seconds on a simple pose and 62 seconds versus 296 seconds on a more complex pose. There were no camera view changes using our method, as one of the constraints was to provide a monocular interface.

The work exposed here provides several advances that make it contribute to the actual state of the art. Our sketch posing tool is one of the few systems that integrates 3D notions into the storyboarder's workflow in an intuitive way, while the majority of the existing tools tend to ignore the issue of 3D, or to impose unnatural and complex interfaces. By following the storyboarder's constraints, we developed a tool that is more suited to his needs. The user does not have to rotate around the model to add more depth information, unlike in (Guay, 2015)'s method. In addition, our tool remains flexible and adaptable, as it can be used with various morphological types, unlike methods relying on databases, such as (Akman et al., 2020). As opposed to (Gouvatsos, 2018)'s technique, our method is automatic and works in real time. The originality of our technique also comes from the combination of several sketch abstractions integrated into three tools that the user can pick instantly according to his needs.

In that way, our system can find applications in the 3D animation industry, as it would be particularly suited to layout, previz and storyboard departments where it could form a practical ideation tool.

7 CONCLUSIONS AND FUTURE WORKS

Although this tool allows to quickly prototype poses, it does not offer as many levels of precision as the classical controller based technique, which affects the quality of the resulting poses. Thus, some points could be deepened in future works to improve our method. For now, our sketch posing system doesn't consider how the character interacts with the 3D environment. As (Lin et al., 2012) did in their research, we should try to implement new constraints in order to avoid collisions with the other 3D objects of the scene and use them to resolve depth ambiguities. Moreover, our tool doesn't take into account the possible movements a character can do according to his morphology, as described in some studies, such as (Lee and Chen, 1985). Thus, in the future, we will pursue the development of our work by adding constraints to prevent the generation of implausible poses. Finally, handling the case of facial expression could be worthwhile. When our method will be significantly improved, we will have to make a better study of its impact on the creative process by organizing testing sessions with storyboard artists and by evaluating in a more relevant way the aesthetic and technical quality of the resulting poses.

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