HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

AUTOMATION ALGORITHMS FOR 2D CHARACTER MOVEMENT IN AFTER EFFECTS AND THEIR OPTIMIZED MODEL

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Doi: https://doi.org/10.5281/zenodo.21415357

Abstract: This article investigates the problems of automating character movements in 2D animation processes, specifically focusing on the principles of overlapping action and follow-through.

Keywords: digital animation, inverse kinematics, overlapping action, software automation, algorithmic modeling, keyframe, interpolation.

Currently, the continuous development of computer graphics and multimedia technologies is causing a number of technical and economic problems associated with digital 2D animation production processes. Animation is the art of creating the illusion of movement, and its modern methodologies require complex software to function seamlessly. Although the Adobe After Effects platform has become a global standard for creating motion design and visual effects, animating characters within it remains a highly labor-intensive task. On average, producing a one-minute professional-level video requires four to eight hours of a specialist's working time. The largest portion of this time, approximately 40 to 60 percent, is spent specifically on repetitive rigging operations and manual keyframe management. From this perspective, reducing redundant operations through automation and increasing animation speed is one of the primary technical tasks facing software developers in the industry.

Overcoming these challenges is necessary not only to save production time but also to facilitate the delivery of high-quality visual products in a highly competitive market. Displaying character movements reliably and naturally directly relies on the specific classical principles of the field. Specifically, principles such as overlapping action and follow-through are crucial in visually proving that each limb or appendage of a character possesses its own weight and elasticity. However, continuously executing these complex physical principles manually imposes a burden on the animator, requiring isolated arithmetic attention for each frame. Therefore, the need arises to control and integrate technical processes at the software level using algorithmic approaches. This, in turn, necessitates the creation of smarter and more efficient tools in computer graphics engineering.

In modern computer graphics, two major stylistic approaches are observed and actively used in the issue of automating character animation. First, there is the procedural approach based on special mathematical codes known as expressions, which is popular and highly flexible within the After Effects system. Through this approach, object movements are determined using complex mathematical equations, but because this process requires continuous recalculation from the computer at every

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single frame, it significantly reduces the overall performance speed of the system. Second, there is the baked approach based purely on keyframes, which focuses directly on the static interpolation of final values. This approach requires very few computational resources and provides the convenience of additional editing for the finished result. International studies confirm that automation algorithms executed through ExtendScript have the potential to increase production efficiency by an average of 67.78 percent.

If we turn to the analysis of tools that are currently available and widely popular in the global market, we can see that the operational logic of many well-known plugins is based precisely on procedural expressions. For example, the Duik toolkit, which has reached the level of a quality standard in the animation industry, provides inverse kinematics capabilities and partially eases the work of animators. However, the functions in its automation section demand an excessively high amount of operating memory load and continuous computational power from the graphics processing unit. Every time the working state on the screen changes or the timeline is scrubbed, the program is forced to recalculate the entire hierarchical system from scratch. This has been analyzed to lead to sharp slowdowns, freezing, and unexpected technical errors in complex projects. Furthermore, in scientific approaches aimed at eliminating such systemic flaws, the development of independent computational modules relying exclusively on baked scripts is increasingly being proposed.

Taking these shortcomings into account and as a practical solution, the entirely original ZiyoAnim Overlap independent module was successfully developed within the scope of this research. This algorithmic system operates based on a completely unique architectural structure for automatically generating and rapidly editing keyframes. The module deeply analyzes the movement parameters of the main selected layer, referred to as the driver, and distributes them accordingly to all other logically connected layers, known as followers. During this mathematical distribution process, a specific time delay for the layers is consistently taken into account. At the same time, the physical movement amplitude of each follower is formed based on the principle of continuous decay. Through this complex mechanism, it becomes possible to ensure that the moving parts of a character, such as hair, clothing, or any long jointed appendages, react to the main body in an absolutely natural manner.

From a mathematical and logical standpoint, this original algorithm strictly relies on a combination of specific delay and exponential decay functions. For each successive follower layer, the temporal extension delay is calculated by directly multiplying the base metric entered by the user by the follower's index number. The resulting physical movement amplitude is determined individually for each layer based on a decreasing parameter integrated into the module's formula. First, the delay for the *i-th* follower is calculated mathematically as $delay_i = D \cdot i \cdot \Delta t$, where the base delay is multiplied by the frame duration. Second, the exponential amplitude decay is structured as $decay_i = r^i$, ensuring realistic loss of momentum. Third, the resulting value is applied using the following formula to seamlessly blend the offset action over the resting state:

$$Q_i(t) = rest_i + decay_i \cdot [driver(t - delay_i) - driver(t_0)]$$

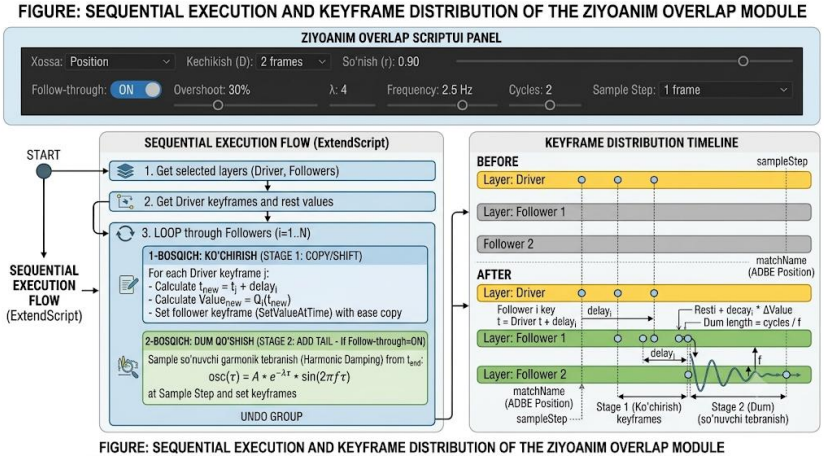
In addition to this, after the leading object has fully completed its movement, a special follower harmonic oscillation is automatically generated by the module. This part, known as the tail or follow-through, is introduced into the system as a decaying wave with an initial amplitude fully proportional to the object's final incoming velocity and a specified frequency. This process prevents noticeable, unexpected hard stops and perfectly ensures continuity that complies with the laws of visual physics.

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The mathematical representation of this tail effect is modeled as a decaying harmonic oscillation formulated as:

$$osc(\tau)=A\cdot\ e^{-\lambda\backslash tau}\cdot\ \backslash sin(2\pi f\tau)$$

This ensures that the generated animation naturally settles into a resting state over the variable time parameter without requiring any manual keyframe adjustments from the user.



1-Figure. Sequential execution and keyframe distribution of the ZiyoAnim Overlap module

Columns/lines: The movement of the driver layer is directly compared with the periodic delay lines of the followers hierarchically attached to it

Data: The initiation of the driver movement occurs at frame zero, the delay of the first follower at frame three, the delay of the second follower at frame six, followed by a precise sequence demonstrating the decaying tail section oscillations between frames ten and fifteen

Colored markers: The blue primary line represents the movement of the driver object, while the red and green descending lines clearly indicate the natural flow of movement based on the amplitude decay of the followers

In order to deeply test this created modular system in practice, ready-made animation projects with various speeds and different framerates were studied in detail. The research trials and monitoring results clearly showed that the automation achieved using the ZiyoAnim Overlap tool was able to maintain absolutely identical and constant quality at speeds of 24, 30, and even the fastest 60 frames per second. The main practical reason for this is that all movement parameters are derived not per frame, but based on a precise mathematical formula, which is directly converted into After Effects' own hard keyframes. Moreover, a specific parameter called the sample step gives the user the freedom to determine the balance between movement quality and keyframe volume according to the project's needs. If a perfectly smooth result is required in inter-frame transitions, the step is reduced; however, in scenes where conserving computer memory is highly crucial, the step is increased. This optimized approach provides the opportunity to allocate resources most efficiently and correctly in highly complex and visually dense scenes.

1-Table.

Comparative metrics of methods for automating character animation

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Parameter	Description	Recommended Value
Property	Automated transformation property (Position/Rotation/Scale/Opacity)	Position
Delay (frames)	Additional time delay applied to each successive follower	1–3
Decay r (0..1)	The retention percentage of the movement amplitude for each joint	0.80–0.92
Follow-through	Toggle to enable or disable the decaying oscillating tail	Enabled
Overshoot (%)	The degree to which the movement overshoots upon ending	20–40
Damping coefficient (λ)	The speed of oscillation decay (higher values mean faster decay)	3–6
Frequency (Hz)	The physical frequency of the tail oscillations	2–3
Oscillation cycles	The number of visible full oscillation cycles in the tail	1.5–3
Sample step (frames)	The step between tail keyframes representing the balance between accuracy and resource economy	1

To summarily express all the obtained algorithmic metrics, the capabilities of manually crafted standard animation, the existing universal Duik plugin, and the newly developed script module were comparatively contrasted based on specific criteria. As criteria for comparative analysis, the ultimate rendering costs of the tools, the number of user actions, the load generated on the system, and the aforementioned dependence on framerate were taken first. For the results to have a clear visual representation, all systematized differences and parameter advantages were compiled and analyzed in a tabular format. This openly proves how lightweight the developed module is on memory from an architectural standpoint. By relying on pre-calculated data points rather than real-time expression evaluation, the algorithmic module fundamentally circumvents the rendering bottlenecks that plague contemporary animation pipelines.

Thus, in the rapid development of modern computer graphics and multimedia animation processes, the engineering-level development of original scripts based on keyframes acquires priority technological significance. Created on the basis of studying the practical limitations of traditional manual labor methods and the excessive load caused by procedural plugins during rendering time, the ZiyoAnim Overlap module distinguishes itself from other tools with its significantly optimized logical structure . In particular, automatically forming the keyframes of overlapping movements and follower oscillations through script functions almost entirely relieves the daily technical and repetitive tasks of specialist animators. Algorithmic and software solutions of this type have very high economic and time-saving significance for professional, highly productive, and most importantly, rapid visual effects preparation services.

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Overall, the theoretical and technical conclusions obtained and measured in practice as a result of this research serve as a very strong foundation for large-scale future directions, such as fully automating the entire character body through a single button click. By further perfecting mathematical models and the speed of data exchange between object hierarchies, it is planned in the future to deepen automation parameters and integrate promising mechanisms such as linking artificial intelligence elements to plugins. This continuous technological process grants both young specialists in the field of motion design and computer graphics, as well as professional studio employees, the opportunity to allocate more resources to implementing their original creative ideas and to operate completely free from complex technical and mechanical barriers.

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