

Audio fade profile customizing by imposing the audio volume initial rate of change

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Abstract. By adopting a rational function of degree 1, with the playback position in the course of an audio fade transition as the function input, and the audio volume as the function output, we advance a technique of setting up the audio fade profile by bringing forward a shape parameter that is directly proportional to the initial rate of change of the audio volume. We provide the relationships that are essential for computing the coefficients of the adopted rational function having at hand the audio effect characteristics, i.e. the fade length, initial volume, final volume and the parameter used for shaping. The versatility of the proposed technique is revealed by the numerous curves illustrating fade in, fade up, fade out and fade down transitions. The shape parameter is of key significance here having in view that it decides the pattern to follow. More precisely, one can set the value of the shape parameter in order to get either a fade effect that acts similar to the exponential shape fade or a fade effect that follows the pattern of the logarithmic shape fade. With a view to real time experimentation, a practical application, developed via plain JavaScript, is provided in the paper.

Keywords. Audio fade profile, audio volume rate of change, fade in, fade up, fade out, fade down, HTML DOM, JavaScript, real time audio.

1. Introduction

The audio fade effects are carried out with the purpose of strictly increasing or decreasing the volume of audio contents [1]-[7]. The process of audio fading is typically operated in audio editors with a focus on off-line processing and exporting audio content. Implementing audio fades could turn out to be a laborious task, especially when transcendental functions are manipulated in order to customize the audio fades profile.

It is well-known that both the fades of exponential shape and the logarithmic shape fades are widely used to set up fade in, fade up, fade out and fade down transitions. The exponential shape fades are characterized by a low initial rate of change of the audio volume in the case of applying fade up effects and by a high absolute value of the audio volume initial rate of change in the situation of performing fade down transitions. On the other hand, the logarithmic shape fades feature a relatively high audio volume initial rate of change in the case of carrying out fade up transitions and a low absolute value of the initial rate of change of audio volume in the case of applying fade down transitions [3]-[7].

To add real time audio capabilities, currently required by a plethora of entertainment and simulation applications [8]-[17], and to speed up the fading process implementation, we will employ a rational function of degree 1 with a view to resembling the exponential fade shape and the logarithmic

fade shape, respectively. Hence, the immediate purpose is to express the coefficients of the adopted rational function in terms of fade characteristics (parameters), which have to include here a shape parameter dependent on the initial rate of change of the audio volume.

2. Building the audio fade profile

With output v designating the audio volume and input τ standing for the playback position, as counted from the effect outset, we consider that the audio transition, of length τ_f , is described by the following degree 1 rational function [7], [18]:

$$v(\tau) = \frac{\tau - \alpha}{\beta\tau - \gamma}, \quad \tau \in [0, \tau_f]. \quad (1)$$

If one imposes v_0 as the initial audio volume, v_f as the final audio volume, and τ_μ as the intermediate playback position at which the audio volume has the mean value μ_v , i.e.

$$v(0) = v_0, \quad v_0 \geq 0, \quad (2)$$

$$v(\tau_f) = v_f, \quad v_f \geq 0, \quad v_f \neq v_0, \quad (3)$$

$$v(\tau_\mu) = \mu_v \equiv (v_0 + v_f)/2, \quad \tau_\mu \in (0, \tau_f) \quad (4)$$

then the three coefficients of (1) get the expressions [7]:

$$\alpha = \tau_f \frac{v_0}{v_0 + (1 - \varepsilon^{-1})v_f} = \alpha(\tau_f, v_0, v_f, \varepsilon), \quad (5)$$

$$\beta = \frac{2 - \varepsilon^{-1}}{v_0 + (1 - \varepsilon^{-1})v_f} = \beta(v_0, v_f, \varepsilon), \quad (6)$$

$$\gamma = \tau_f \frac{1}{v_0 + (1 - \varepsilon^{-1})v_f} = \gamma(\tau_f, v_0, v_f, \varepsilon), \quad (7)$$

wherein

$$\varepsilon = \tau_\mu/\tau_f, \quad \varepsilon \in (0, 1). \quad (8)$$

To prove that rational function (1) is strictly monotonic on the fade interval, i.e. $[0, \tau_f]$, one has to scrutinize the expression of the audio volume instantaneous rate of change. Based on relation (1), where the coefficients are provided by (5)-(7), we have [7]

$$\frac{dv}{d\tau} = \frac{(\varepsilon^{-1} - 1) \tau_f}{[v_0 + (1 - \varepsilon^{-1}) v_f]^2 (\beta\tau - \gamma)^2} (v_f - v_0) \quad (9)$$

and, thus,

$$\text{sgn}\left(\frac{dv}{d\tau}\right) = \text{sgn}(v_f - v_0), \quad (10)$$

what highlights the monotonicity of (1) in the presence of the audio volume initial and final values.

Having recourse to (9), one receives the expression of the audio volume initial rate of change:

$$\left.\frac{dv}{d\tau}\right|_{\tau=0} = \frac{(\varepsilon^{-1} - 1) \tau_f}{[v_0 + (1 - \varepsilon^{-1}) v_f]^2 \gamma^2} (v_f - v_0). \quad (11)$$

Having in view (7), the initial rate of change of the audio volume gets the expression:

$$\begin{aligned} \left. \frac{dv}{d\tau} \right|_{\tau=0} &= \frac{(\varepsilon^{-1} - 1) \tau_f}{[v_0 + (1 - \varepsilon^{-1}) v_f]^2 \frac{1}{[v_0 + (1 - \varepsilon^{-1}) v_f]^2} \tau_f^2} (v_f - v_0) \\ &= (\varepsilon^{-1} - 1) \frac{v_f - v_0}{\tau_f} = (\varepsilon^{-1} - 1) \frac{v(\tau_f) - v(0)}{\tau_f}. \end{aligned} \quad (12)$$

Within (12), we identify the average rate of change of the audio volume over the fade interval $[0, \tau_f]$, that is:

$$m = \frac{v(\tau_f) - v(0)}{\tau_f}. \quad (13)$$

Thus, the rate of change of the audio volume at the fade initiation, yielded by (12), comes to be:

$$m_0 = \left. \frac{dv}{d\tau} \right|_{\tau=0} = (\varepsilon^{-1} - 1) m. \quad (14)$$

From relationship (14), we straightforwardly find out:

$$\varepsilon^{-1} - 1 = m_0/m > 0. \quad (15)$$

With (15), one perceives that the three coefficients in (1), originally given by (5)-(7), can now be expressed in terms of the ratio of the audio volume initial rate of change to the audio volume average rate of change over the fade interval, i.e.

$$\alpha = \tau_f \frac{v_0}{v_0 - \frac{m_0}{m} v_f} = \tau_f \frac{v_0}{v_0 - r_0 v_f} = \alpha(\tau_f, v_0, v_f, r_0); \quad (16)$$

$v_0 \neq r_0 v_f,$

$$\beta = \frac{1 - \frac{m_0}{m}}{v_0 - \frac{m_0}{m} v_f} = \frac{1 - r_0}{v_0 - r_0 v_f} = \beta(v_0, v_f, r_0); \quad (17)$$

$v_0 \neq r_0 v_f,$

$$\gamma = \tau_f \frac{1}{v_0 - \frac{m_0}{m} v_f} = \tau_f \frac{1}{v_0 - r_0 v_f} = \gamma(\tau_f, v_0, v_f, r_0); \quad (18)$$

$v_0 \neq r_0 v_f,$

where

$$r_0 = m_0/m \quad (19)$$

represents here precisely the shape parameter.

With expressions (16)-(18) of the coefficients interfering in (1), the instantaneous rate of change of the audio volume becomes:

$$\frac{dv}{d\tau} = \frac{r_0 \tau_f}{(v_0 - r_0 v_f)^2 (\beta \tau - \gamma)^2} (v_f - v_0), \quad (20)$$

what is equivalent to

$$\frac{dv}{d\tau} = \frac{r_0 \tau_f}{[(1-r_0)\tau - \tau_f]^2} (v_f - v_0) \quad (21)$$

since one identifies

$$\beta\tau - \gamma = \frac{(1-r_0)\tau - \tau_f}{v_0 - r_0 v_f}.$$

Having at hand the audio volume initial and final values, expressions (20) and (21) emphasize the monotonicity of rational function (1), considering that the sign of audio volume rate of change is being kept identical to the sign of difference $\Delta v \equiv v_f - v_0 \neq 0$.

Taking into account (1), wherein the coefficients are yielded by (16)-(18), one obtains the audio volume at the fade halfway point [18] as dependency on the shape parameter (19), i.e.

$$v_h = v\left(\frac{\tau_f}{2}\right) = \frac{\frac{\tau_f}{2} - \frac{\tau_f v_0}{v_0 - r_0 v_f}}{\frac{1-r_0}{v_0 - r_0 v_f} \frac{\tau_f}{2} - \frac{\tau_f}{v_0 - r_0 v_f}} = \frac{v_0 + r_0 v_f}{1 + r_0}. \quad (22)$$

3. Fade shapes

Maintaining the transition duration at $\tau_f = 5$ s, the fade profiles put forward in Fig. 1 till Fig. 6 have been built up, on a linear scale, via relationships (1), (16)-(18) for the different values of parameter (19), initial audio volume (2) and of final audio volume (3), respectively. Since the initial volume is equal to 0, all profiles of Fig. 1 designate fade in audio effects, whilst the profiles illustrated in Fig. 2 and Fig. 3 all correspond to audio fade ups as the initial audio volume is different from 0. Likewise, since the final audio volume of the transitions in Fig. 4 is equal to 0, the associated profiles depict a set of 5 s fade out effects, whereas the shapes of Fig. 5 and Fig. 6 plainly spotlight fade down effects.

One observes that the curves in Fig. 1, Fig. 2 and Fig. 3, which have been received for the shape parameter r_0 in the set $\{0.05, 0.1\}$, resemble the exponential fade shape, while the profiles of Fig. 1, Fig. 2, Fig. 3, which correspond to r_0 in $\{3, 5\}$, depict fade effects that act similar to the logarithmic shape fades. More precisely, having in view the transitions advanced in Fig. 1, Fig. 2 and Fig. 3, one notices that for shape parameter in the set $\{0.05, 0.1\}$, the initial rate of change of the audio volume is small enough to get relatively low volumes at the halfway point, while, for the shape parameter in the set $\{3, 5\}$, the audio volume initial rate of change is raised enough so as to receive high volumes at the effect midpoint i.e. 2.5 s. For instance, according to (22), the audio volume at the halfway point of the fade in transition of Fig. 1, which corresponds to $r_0 = 0.05$, has the value of 0.0476. On the other side, the audio volume at the midpoint of the fade in depicted in Fig. 1, corresponding to $r_0 = 5$, has the value of 0.833.

Furthermore, a close look at the fade profiles of Fig. 4, Fig. 5 and Fig. 6 reveals that the transitions obtained for the shape parameter r_0 in the set $\{0.2, 0.35\}$ resemble the logarithmic shape fades, while the transitions associated to the shape parameter in $\{10, 20\}$ are acting similar to the exponential shape fades. This is because, for r_0 in $\{0.2, 0.35\}$, the absolute value (modulus) of the audio volume initial rate of change is small enough to receive a relatively high volume at the effect midpoint, whilst, for the shape parameter in $\{10, 20\}$, the absolute value of the initial rate of change of the audio volume is sufficiently high so as to get relatively low volumes at the transition midpoint that is 2.5 s.

The fact that the shape parameter stands positive for all the profiles of Fig. 1 till Fig. 6 makes us flash back to relation (19), which clearly indicates that the shape parameter also depends on the average rate of change of the audio volume (13), which is positive for the effects depicted in Fig. 1, Fig. 2, Fig. 3 and negative for the transitions portrayed in Fig. 4, Fig. 5 and Fig. 6.

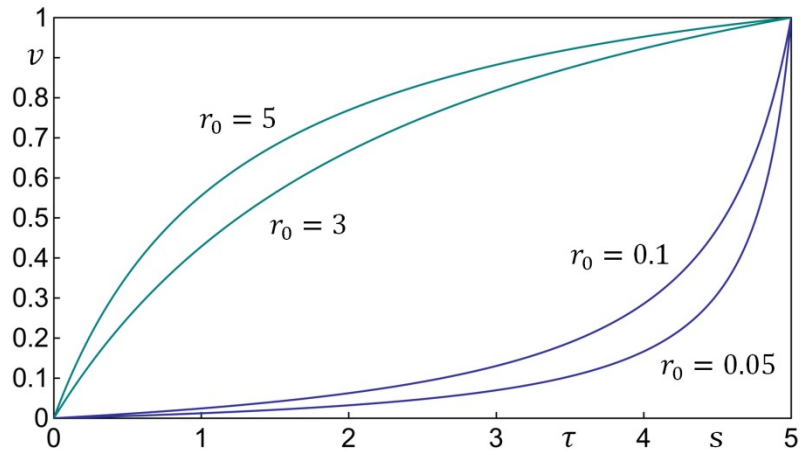


Fig. 1. Fade in profiles, received for the final audio volume of 1 and parameter (19) in the set $\{0.05, 0.1, 3, 5\}$.

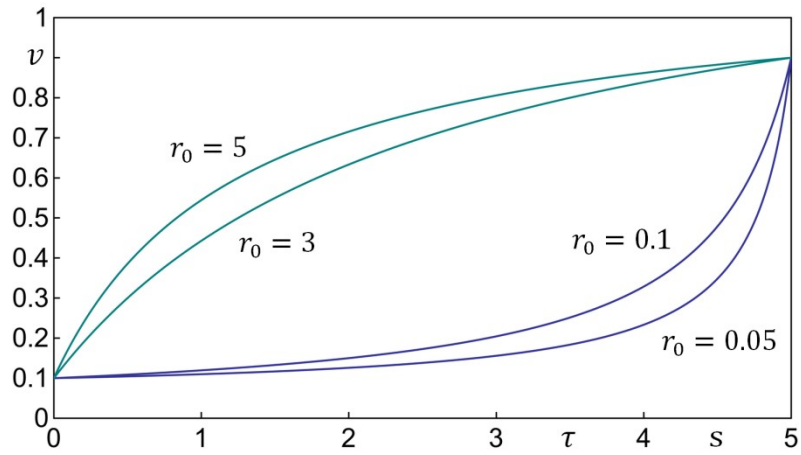


Fig. 2. Fade up profiles, received for the initial audio volume of 0.1, final audio volume of 0.9 and parameter (19) in the set $\{0.05, 0.1, 3, 5\}$.

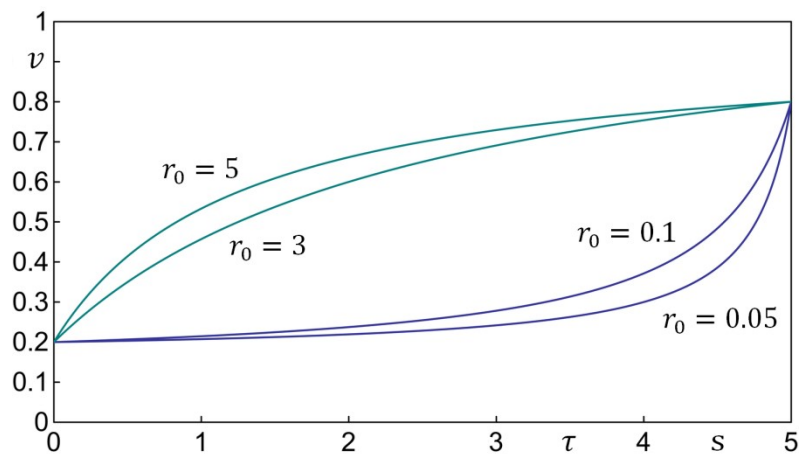


Fig. 3. Fade up profiles, received for the initial audio volume of 0.2, final audio volume of 0.8 and parameter (19) in the set $\{0.05, 0.1, 3, 5\}$.

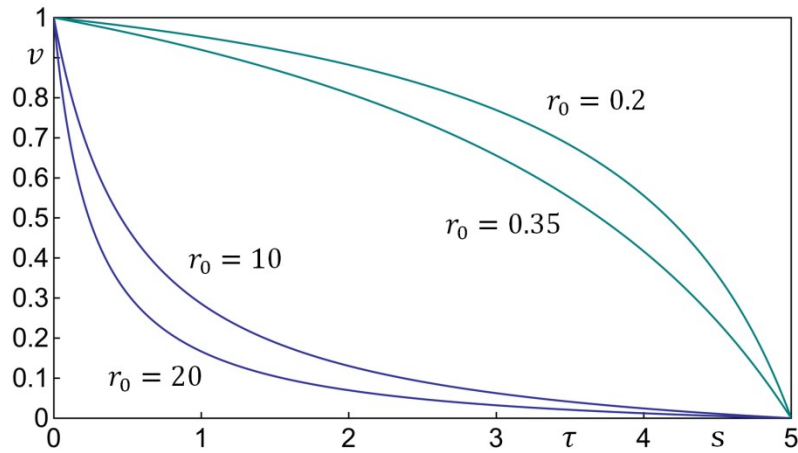


Fig. 4. Fade out profiles, received for the initial audio volume of 1 and parameter (19) in the set $\{0.2, 0.35, 10, 20\}$.

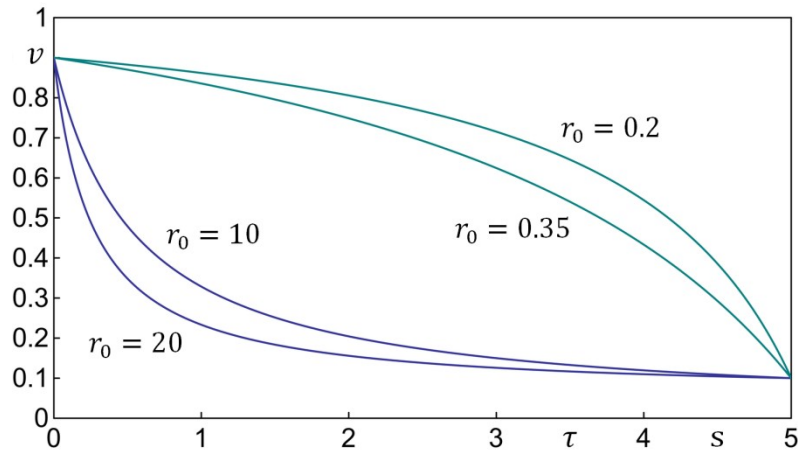


Fig. 5. Fade down profiles, received for the initial audio volume of 0.9, final audio volume of 0.1 and parameter (19) in the set $\{0.2, 0.35, 10, 20\}$.

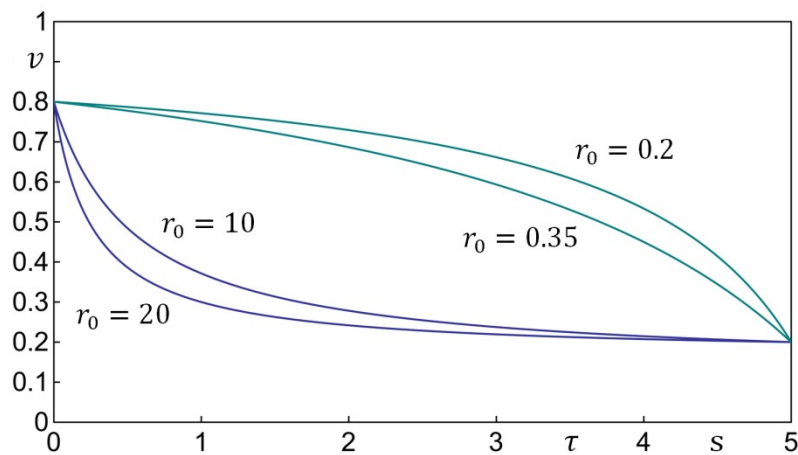


Fig. 6. Fade down profiles, received for the initial audio volume of 0.8, final audio volume of 0.2 and parameter (19) in the set $\{0.2, 0.35, 10, 20\}$.

4. Practical application

The plain JavaScript code, which is put forward in the next listing, implements the fade up transition depicted in Fig. 2, corresponding to the shape parameter of 3.

```

<!DOCTYPE html>
<html>
<head>
<title>Fading</title>
</head>
<body>
<script>

var alpha, beta, gamma; /* the coefficients of rational function (1) */
var audElm; /* the audio object */
var tmrId; /* the timer id returned by setInterval() method */

function calcAlphaBetaGamma( tauF, v0, vF, r0 ) {
  /* computes the three coefficients of function (1) */
  gamma = v0 - r0 * vF;
  beta = ( 1.0 - r0 ) / gamma; /* according to expression (17) */
  gamma = tauF / gamma; /* according to expression (18) */
  alpha = gamma * v0; /* according to expression (16) */
}
function evalV( tauF ) {
  /* implementation of rational function (1) */
  var tau = audElm.currentTime; /* input of (1) */
  if ( tau <= tauF ) {
    var vAtTau = ( tau - alpha ) / ( beta * tau - gamma );
    audElm.volume = vAtTau; /* output of (1) */
  }
  else { /* tau > tauF */
    /* fading process ending (clears the timer) */
    window.clearInterval( tmrId );
  }
}
function audFading() {
  /* audio fading over the interval [0 s, tauF] i.e. [0 s, 5 s] */
  audElm.currentTime = 0.0;
  audElm.volume = 0.1; /* v0 = 0.1 */
  tmrId = window.setInterval( evalV, 50, 5.0 );
  /* calls evalV() once every 50 ms and passes the fade length of 5 s */
}
function fadeOnPlay( tauF, v0, vF, r0, audSrc ) {
  /* tauF - fade length, v0 - initial volume, vF - final volume,
  r0 - shape parameter, audSrc - location of the audio content */
  calcAlphaBetaGamma( tauF, v0, vF, r0 );
  audElm = document.createElement( "AUDIO" );
  audElm.src = audSrc;
  audElm.controls = true;
  audElm.addEventListener( "play", audFading );
  /* initiates the audio fading when the playback has started */
  document.body.appendChild( audElm );
}
fadeOnPlay( 5.0, 0.1, 0.9, 3.0, "sample.mp3" );
/* tauF = 5 s, v0 = 0.1, vF = 0.9, r0 = 3,
audSrc = "sample.mp3" (indicates audio/mpeg media) */

</script>
</body>
</html>

```

Provided that the user indicates the location of the audio content (sample), the resulted application proved to be suitable for experimentation in any mainstream browser. Mapping (1), with the audio volume as the output, is implemented within function “evalV()” whilst the whole process of discretization is achieved via the “setInterval()” method of the “window” object [19], which is employed here to invoke function “evalV()” once every 50 ms. Taking into account that the three coefficients in (1) depend on the fade characteristics (parameters), they are computed only once, according to relationships (16)-(18), by plainly calling function “calcAlphaBetaGamma()”. Implicitly, the values of the coefficients interfering in mapping (1) are stored in variables of global scope, namely “alpha”, “beta” and “gamma”. As the code of function “fadeOnPlay()” emphasizes, the fading up process is initiated as soon as the playback has started, and, having in view the arguments of invoking this function, the transition will follow here the pattern of the logarithmic fades.

5. Conclusion

Traditionally, the audio fade profiles are built up in the off-line mode, by making use of different transcendental functions. The audio fades customization is usually implemented within audio editors and predominantly calls for evaluation of exponential or logarithm functions, giving rise to laborious and time-consuming procedures.

To effectively carry out the audio fading process in real time, the degree 1 rational function, yielded by relation (1), has been employed to portray the fade profile. The input of (1) is represented by the current playback position within the transition, i.e. the playback position figured up from the fade starting point, while the output of (1) stands for the current audio volume. As a result of introducing the shape parameter (19), which varies based on the audio volume initial rate of change, the three coefficients of rational function (1) have been expressed in terms of fade characteristics by means of relationships (16)-(18). Moreover, since the fade characteristics are represented not only by the fade length and the parameter advanced here with the purpose of fade shaping but also by the audio volume extrema, function (1) can be employed to apply a variety of adjustable fades such as fade in, fade up, fade out and fade down transitions.

Although the provided application has been developed to generate the effect illustrated in Fig. 2, and corresponding to the shape parameter of 3, within the JavaScript code, one can straightforwardly alter the arguments used to invoke function “fadeOnPlay()” to get different transitions. Additionally, when changing the fade length, one has to take into consideration that the “setInterval()” method, adopted for discretization, passes the value of fade length to function “evalV()”, which implements here mapping (1).

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