The Tromba Marina: a physical modelling case study (#superbadandpretentious)

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I. INTRODUCTION

Physical modelling for sound synthesis knows a wide variety of applications. . .

Another is to make unplayable instruments, due to rarity or fragility, playable again. Our focus here is to resurrect the old and rare tromba marina.

A. History

The tromba marina is a monochord from <insert country> and created in ca. <insert year> (see 1). It was played mainly by women. The characteristic sound of the instrument comes from the rattling bridge, that makes the instrument sound like a trumpet rather than a bowed-string instrument.

Non-iterative collisions as presented in[?] . . .

In[?], the same authors have published a continuation with a focus on sonic output quality. To the best of the authors' knowledge, no other literature

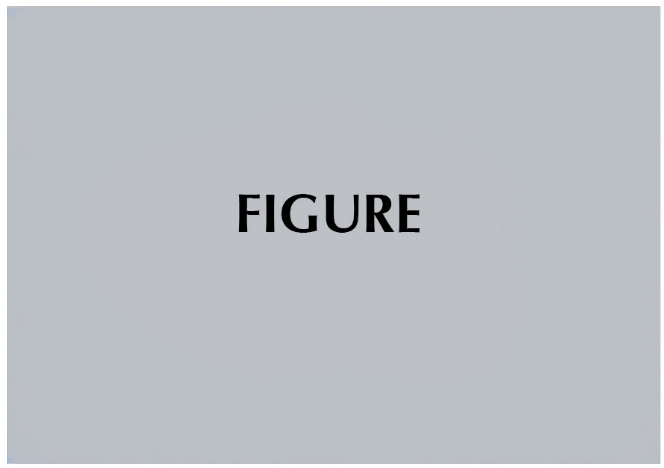

FIG. 1. The tromba marina.

II. INSTRUMENT DESIGN AND INTERACTION

The tromba marina is a chordophone... The interaction with the instrument is through bowing. The string rests on a rattling bridge, causing the sound of the instrument to have brass-like qualities. The instrument rests with the neck on the shoulder of the player and the string is bowed close to the neck – as opposed to other bowed-string instruments which are bowed closer to the bridge. Different pitches are played by playing overtones or harmonics by placing a finger slightly on a one-over-integer multiple of the string length to create a node creating an overtone. ⇐ *Notes: need to find better wording.*

The instrument can be divided into three main components: the (bowed) string, the bridge and the body.

III. MODELS

In this section the model equations will be presented.

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a. Notation. Subscripts 't' and 'x' denote a single derivative with respect to time or space. Furthermore, for clarity, subscripts 's' and 'p' will be given for parameter symbols that are shared between the string and the plate.

A. Damped Stiff String

Using state variable $u = u(x,t)$, the motion of a damped stiff string is described as

$$\rho_\mathrm{s} A u_{tt} = T u_{xx} - E_\mathrm{s} I u_{xxxx} - 2\rho_\mathrm{s} A \sigma_{0,\mathrm{s}} u_t + 2\rho_\mathrm{s} A \sigma_{1,\mathrm{s}} u_{txx}, \tag{1}$$

with material density ρ_s (kg·m^{-3}), cross-sectional area $A = \pi r^2$ (m^2), where r is the string radius (m), tension T (N), Young's modulus E_s (Pa), area moment of inertia $I = \pi r^4/4$ (m^4) and frequency independent and dependent loss factors $\sigma_{0,\mathrm{s}}$ (s^{-1}) and $\sigma_{1,\mathrm{s}}$ (m^2/s).

B. Bridge

The bridge is modelled as a damped mass with a linear restoring force. Its displacement $w = w(t)$ is described as

$$M w_{tt} = -M\omega_0^2 w - MR w_t, \tag{2}$$

with bridge-mass M (kg), angular frequency ω_0 (s^{-1}) and damping coefficient R (s^{-1}). The restoring force has been added to simulate the fact that... It might seem odd have all terms include a multiplication with mass M, but as we start adding the effects of other parts of the system, it will make more sense.

C. Body

For simplicity, the body is modelled as a 2D plate. The displacement $v = v(x,y,t)$ at location (x,y) is described as

$$\rho_\mathrm{p} H v_{tt} = -D\Delta\Delta v - 2\sigma_{0,\mathrm{p}} v_t + 2\sigma_{1,\mathrm{p}} \Delta v_t, \tag{3}$$

with material density ρ_p (kg·m^3), plate thickness H (m), $D = E_\mathrm{p} H^3/12(1-\nu^2)$ (kg·m^2·s^{-2}), where E_p is the Young's modulus (Pa) and ν the unitless Poisson's ratio, and and frequency independent and dependent loss factors $\sigma_{0,\mathrm{p}}$ (s^{-1}) and $\sigma_{1,\mathrm{p}}$ (m^2/s). Furthermore, Δ represents the 2D Laplacian and is defined as

$$\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}. \tag{4}$$

D. Implementation

The complete system is shown in Eqs. (5a) – (5g).

$$\begin{cases}
\rho_\mathrm{s} A \delta_{tt} u_l^n = T\delta_{xx} u_l^n - E_\mathrm{s} I \delta_{xxxx} u_l^n - 2\rho_\mathrm{s} A \sigma_{0,\mathrm{s}} \delta_{t\cdot} u_l^n + 2\rho_\mathrm{s} A \sigma_{1,\mathrm{s}} \delta_{t-}\delta_{xx} u_l^n - J_\mathrm{s}(l_\mathrm{br}) F_\alpha & \text{(5a)} \\
M\delta_{tt} w^n = -M\omega_0^2 w^n - MR\delta_{t\cdot} w^n + \left(\mu_{t+}\psi^{n-1/2}\right) g^n + F_\alpha & \text{(5b)} \\
\rho_\mathrm{p} H \delta_{tt} v_{(l,m)}^n = -D\delta_{\Delta\boxplus}\delta_{\Delta\boxplus} v_{(l,m)}^n - 2\sigma_{0,\mathrm{p}}\delta_{t\cdot} v_{(l,m)}^n + 2\sigma_{1,\mathrm{p}}\delta_{t-}\delta_{\Delta\boxplus} v_(l,m)^n - J_\mathrm{p}(l_\mathrm{br}, m_\mathrm{br})\left(\mu_{t+}\psi^{n-1/2}\right) g^n & \text{(5c)} \\
\delta_{t+}\psi^{n-1/2} = g^n \delta_{t\cdot}\eta_\mathrm{c}^n & \text{(5d)} \\
\eta_\mathrm{c}^n = v_{(l_\mathrm{br}, m_\mathrm{br})}^n - w^n & \text{(5e)} \\
F_\alpha = K_1 \mu_{tt}\eta_\mathrm{sp}^n + K_3(\eta_\mathrm{sp}^n)^2 \mu_{t\cdot}\eta_\mathrm{sp}^n + 2\sigma_\times \delta_{t\cdot}\eta_\mathrm{sp}^n & \text{(5f)} \\
\eta_s^n = u_{l_\mathrm{br}}^n - w^n & \text{(5g)}
\end{cases}$$

The time-difference operators have been chosen so that the system is as accurate as possible while still being explicit

Compare the results you get with
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vs.
`\documentclass[preprint,NumberedRefs]{JASAnew}`