Physical Modeling meets Machine Learning: Teaching Bow Control to a Virtual Violinist

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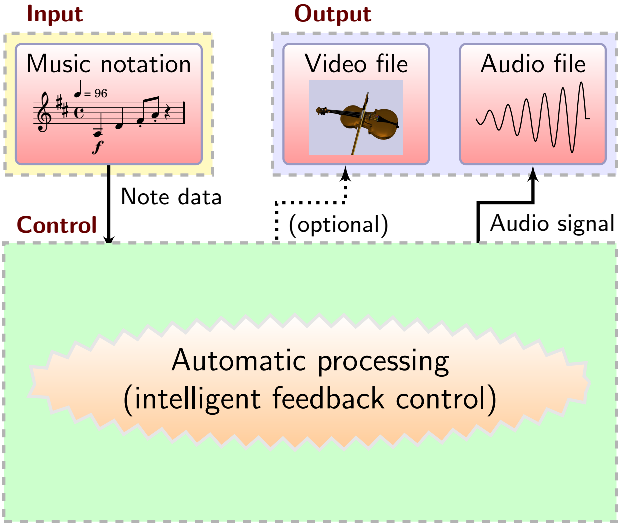
http://percival-music.ca/vivi.html

Teaching Bow Control to a Virtual Violinist

1. Introduction
   - Music performance with *Vivi, the Virtual Violinist*
2. Performing on a virtual instrument
   - Generating sound: Physical modeling of a violin
   - Pedagogical inspiration for physical parameters
3. Intelligent control loop
   - Intelligent feedback control of bow force
   - Automatically determining other parameters
4. Making music
   - Musical performance style
   - Conclusion and future work

Music performance with *Vivi, the Virtual Violinist*



Input

Music notation

Output

Video file

Audio file

Note data

(optional)

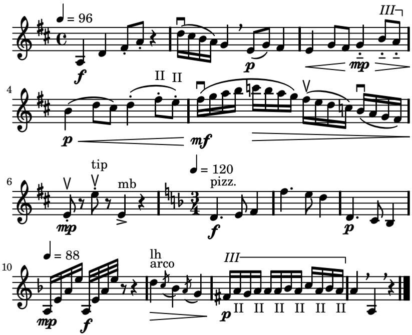
Audio signal

Control

Automatic processing
(intelligent feedback control)

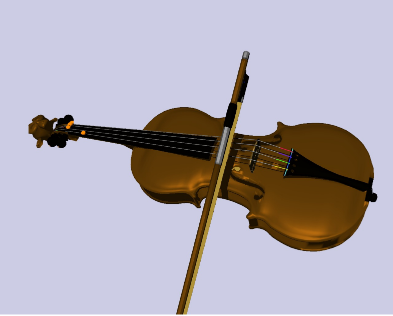
Music example: “black-box testing”

Input



(pdf produced with GNU LilyPond, MusicXML input also possible)

Output



Video: black-box.mpeg

Generating sound: Physical modeling of a violin

- No recordings of violin performance; we use physics [1]
  - Wave equation for a stiff string with modal dampening

$$\rho_{\mathrm{L}} \frac{\partial^2 y(x,t)}{\partial t^2} - T \frac{\partial^2 y(x,t)}{\partial x^2} + EI \frac{\partial^4 y(x,t)}{\partial x^4} + R_L(\omega) \frac{\partial y(x,t)}{\partial t} = F(x,t)$$

[1] M. Demoucron, "On the control of virtual violins: Physical modelling and control of bowed string instruments," Ph.D. dissertation, IRCAM, Paris, 2008

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- Implemented as a C++ library, published under GNU GPLv3+

Input parameters

- Violin string number s
- Left-hand finger position x_1
- Bow-bridge distance x_0, velocity v_b, force F_{b}

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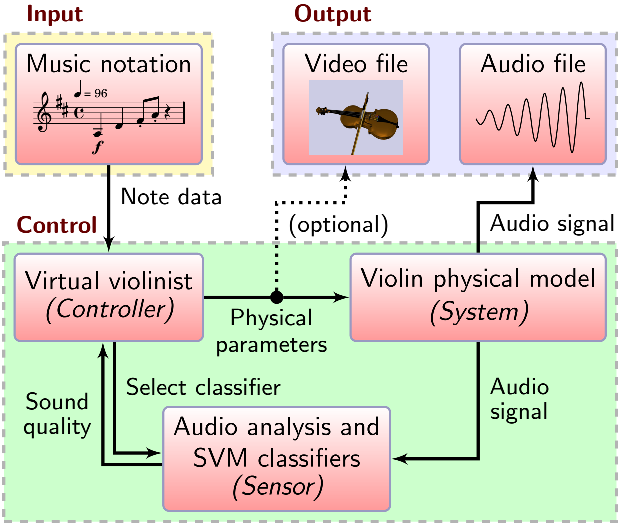

Pedagogical inspiration for physical parameters

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  - Suzuki violin book 1
  - Treat *Vivi* like a beginning student

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  - Bow-bridge distance x_0: dynamic "bow lanes" or "Kreisler Highway"
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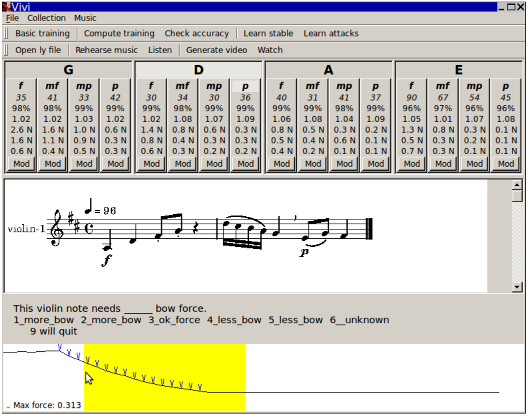
  - Bow velocity v_b: teacher saying “use half bow” and giving tempo
- Bow force F_b from SVM classifiers
  1. not audible: needs a lot more bow force (example)
  2. “whispy”: needs a little more bow force (example)
  3. acceptable: no change (example)
  4. “harsh”: needs less bow force (example)
  5. not recognizable: needs much less bow force (example)

Interactive training

- Basic training: only 32 files (bad example)
- After interactive training: 203 files (good example)
- ≈ 4 hours to be fully trained (including calculations)

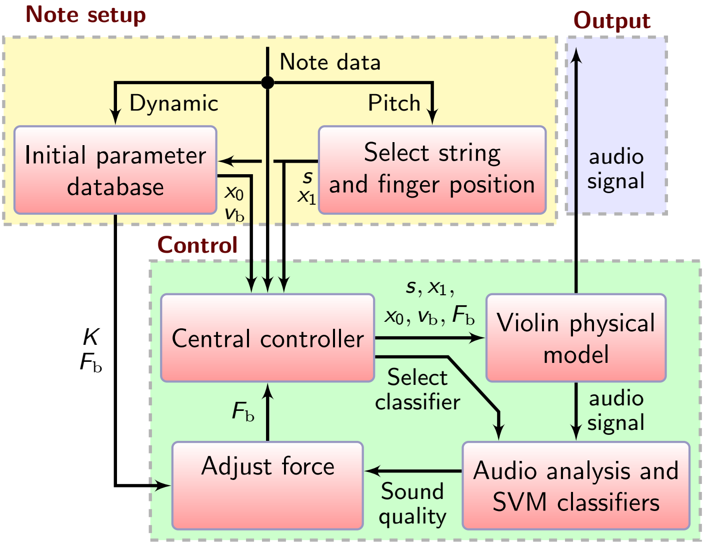


G				D				A				E			
f	*mf*	*mp*	*p*	*f*	*mf*	*mp*	*p*	*f*	*mf*	*mp*	*p*	*f*	*mf*	*mp*	*p*
35	*41*	*33*	*42*	*30*	*34*	*30*	*36*	*40*	*31*	*41*	*37*	*90*	*67*	*54*	*45*
98%	98%	99%	99%	99%	98%	99%	99%	99%	99%	98%	99%	96%	97%	96%	96%
1.02	1.02	1.03	1.02	1.02	1.08	1.07	1.09	1.06	1.08	1.04	1.09	1.05	1.01	1.07	1.08
2.6 N	1.6 N	1.0 N	0.6 N	1.4 N	0.8 N	0.6 N	0.3 N	0.8 N	0.5 N	0.3 N	0.2 N	1.3 N	0.8 N	0.3 N	0.1 N
1.6 N	1.1 N	0.9 N	0.3 N	0.8 N	0.4 N	0.3 N	0.3 N	0.5 N	0.4 N	0.6 N	0.1 N	0.5 N	0.3 N	0.2 N	0.1 N
0.6 N	0.4 N	0.5 N	0.3 N	0.6 N	0.3 N	0.2 N	0.2 N	0.4 N	0.2 N	0.1 N	0.1 N	0.7 N	0.3 N	0.1 N	0.1 N
Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod

This violin note needs _____ bow force.
1_more_bow 2_more_bow 3_ok_force 4_less_bow 5_less_bow 6__unknown
9 will quit

Max force: 0.313

Intelligent feedback control of bow force



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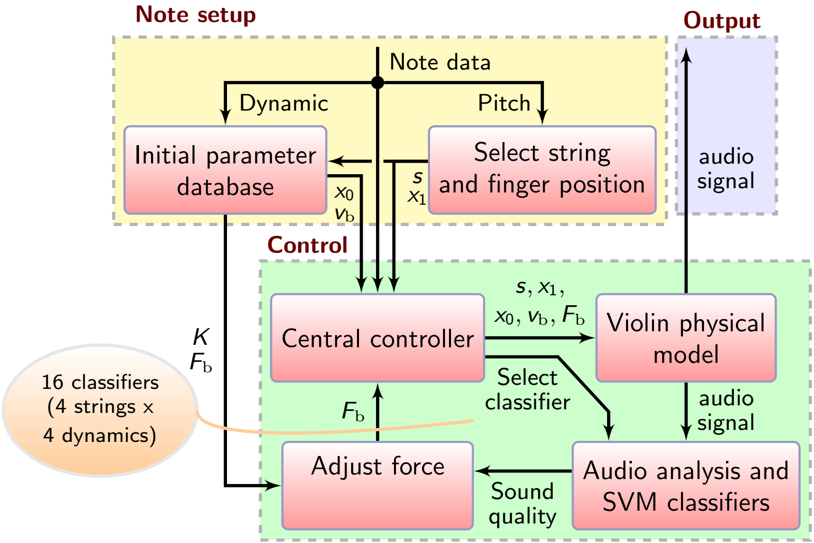

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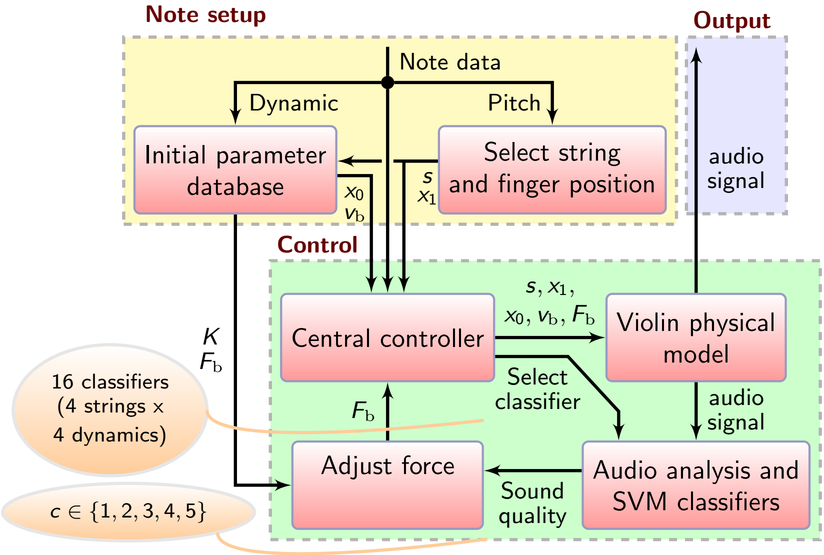

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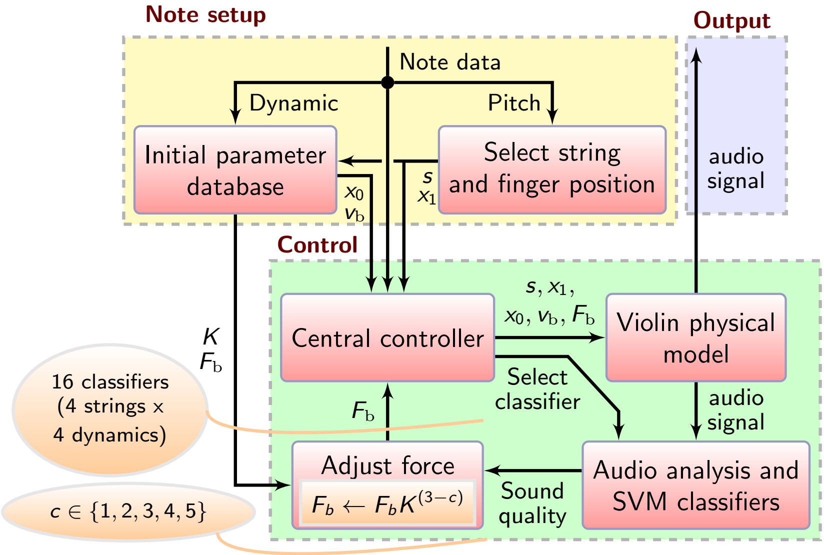
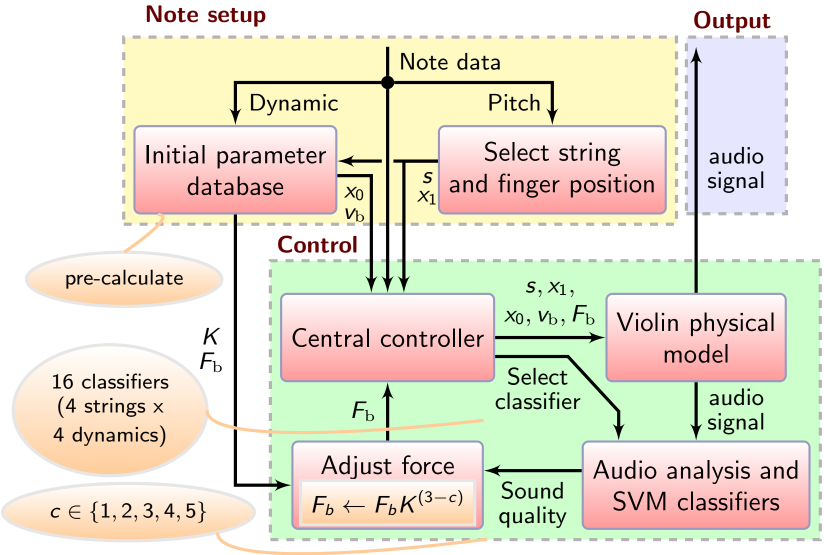

Note setup
Output
Note data
Dynamic
Pitch
Initial parameter database
Select string and finger position
x_0
v_b
s
x_1
audio signal
Control
Central controller
$s, x_1,$
$x_0, v_\mathrm{b}, F_\mathrm{b}$
Violin physical model
K
F_b
Select classifier
F_b
audio signal
16 classifiers (4 strings x 4 dynamics)
Adjust force
$F_b \leftarrow F_b K^{(3-c)}$
Sound quality
Audio analysis and SVM classifiers
$c \in \{1, 2, 3, 4, 5\}$

Intelligent feedback control of bow force



Automatically determining K

Cost of a candidate K

1. Play a simple musical pattern
2. Get list C of judgements c
3. Split C into sublists A_i based on c changing from below to above 3 (and vice versa)
4. Calculate
$$\text{cost} = \prod_{i}^{|A|} \sum_{c \in A_i} (3 - c)^2$$
5. Repeat 12 times and find the inter-quartile geometric mean

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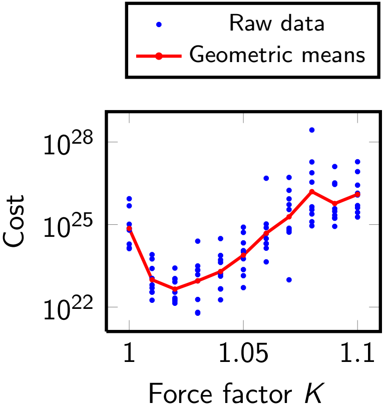
Sample force factors of the D string played *mf*



Automatically determining initial bow force F_b

Cost of a candidate initial F_b

1. Play a simple musical pattern
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3. Split of C into list A (note attack): attack is over when
$$0.5 > \frac{1}{N} \sum_{c \in L_N} (3 - c)^2$$
($L_N =$ previous N values of C)
4. Calculate
$$\mathrm{cost} = \sum_{c \in A} (3 - c)^2$$
5. Repeat 4 times and find the inter-quartile geometric mean

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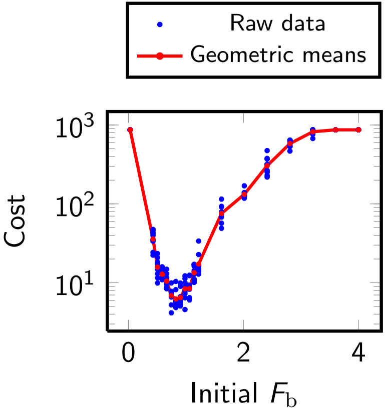
Sample initial forces of the D string played *mf*, open string



Musical performance style

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    "Make it sound like a book 1 Suzuki student."
- Short-term: let humans specify/adjust stylistic interpretation
  - Most beginning music students (age 4–8 years) simply follow instructions from their teachers
  - Humans should give high-level judgements ($\approx$ 1–10 Hz); computers should do low-level processing (control parameters at $\approx$ 172 Hz)

Conclusion and future work

- *Vivi* performs music with a similar skill level to Suzuki violin students with 1 year of experience
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  - Artifastring ("artificial fast string"): violin physical modeling library, C++ with SWIG bindings
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- Future work: apply these techniques to "continuous excitation" instruments in STK (Synthesis ToolKit in C++)
  - Clarinet, saxophone, flute, brass