#### Preserving User-Defined Expression through Dimensionality Reduction

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#### "new control strategies for an aging electronic music instrument" -Lauren

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#### "the sweet spots are all over the place, they're not contiguous, are they?" -Owen

Ted Moore, Doctoral Fellow in Music Composition University of Chicago



### The Goal

Using sound generators that have a high dimension of control inputs,

find expressively meaningful combinations of input settings,

then intelligently organize those combinations into fewer dimensions (using unsupervised learning).



Hypothesis

Dimensionality reduction can enhance musical expression by enabling quick, interpolated, and gestural movements through high dimensional spaces.

Unsupervised learning strategies, will create more useful and meaningful (e.g., expressive) low dimensional latent spaces than supervised strategies.

Supervised strategies require one to know the structure of the high dimensional space and low dimensional space ahead of time...



#### Related Work

- Fasciani and Wyse (2012)
  - "The optimal mapping is defined as the one allowing the widest a sonic exploration"
  - "we assume a *deterministic* behaviour, excluding the presence of any stochastic component within the chain."



|            | 0: FBFM |       |   | 000                | ML M                     | apper          |             |          |
|------------|---------|-------|---|--------------------|--------------------------|----------------|-------------|----------|
| decimate1  |         | 20    | A | CREATE TRAININ     | G SET:                   |                |             |          |
| bitCrush1  |         | 10.53 | A | Audio Bus:         |                          | Params:        |             |          |
| decimate2  |         | 20000 | A | Add to Set         | Ran                      | dom            | Poisson     |          |
| bitCrush2  |         | 1     | A | =======            |                          | <br>`          |             |          |
| cfreq      |         | 20000 | A | TRAINING:          | TSNE Grid (2 dim         | <b>•</b>       |             |          |
| mfreq      |         | 20000 | A |                    | Usir                     | ig Audio Desc. | Irain       |          |
| dev1       |         | 10.7  | A | PEBEOBMING:        | Show Display             | Snan OFF       | Bus not Pre | d        |
| dev2       |         | 12    | A | AutoNorm ON        | Vol Handle:              |                | Free        | <u> </u> |
| distortion |         | 100   | A | Load Model         | ]                        | L              |             |          |
| fb1        |         | 1.38  | A | ======             | )<br>=================== |                |             |          |
| fb2        |         | 2     | A | Post Data          | Save Data                | Load Data      | Save Mappe  | ər       |
| delModFreq |         | 50    | A | =======            |                          | ~              |             |          |
| no         | t held  |       |   | INPUTS             | Make                     | Clear          |             |          |
|            |         |       |   |                    |                          |                |             |          |
|            |         |       |   | OUTPUTS            |                          |                |             |          |
|            |         |       |   | cavityMatrix layer | 0 cavity0 module F       | BFM decimate1  | Delete      |          |
|            |         |       |   |                    |                          | 0              | Not Held A  |          |
|            |         |       |   | cavityMatrix layer | 0 cavity0 module F       | BFM bitCrush1  | Delete      |          |
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|            |         |       |   | cavityMatrix layer | 0 cavity0 module F       | BFM decimate2  | Delete      |          |
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|            |         |       |   |                    |                          |                |             |          |
|            |         |       |   | cavityMatrix layer | o cavityo module F       |                | Delete      |          |
|            |         |       |   |                    |                          |                |             |          |

| • • • 0: FBFM |       |   |                    |             |              |               |                   |        |
|---------------|-------|---|--------------------|-------------|--------------|---------------|-------------------|--------|
| decimate1     | 20    | Α | CREATE TRAININ     | IG SET:     |              |               |                   |        |
| bitCrush1     | 10.53 | Α | Audio Bus:         |             |              | Params:       |                   |        |
| decimate2     | 20000 | Α | Add to Set         |             | Rand         | lom           | Poisson           |        |
| bitCrush2     | 1     | A |                    |             |              |               |                   |        |
| cfreq         | 20000 | A | TRAINING:          | TSNE G      | Grid (2 dim) |               | Troir             |        |
| mfreq         | 20000 | A |                    |             | Using        | g Audio Desc. | Irair             | 1      |
| dev1          | 10.7  | Α | PERFORMING:        | Show [      | Display      | Snap OFF      | Bus not l         | Pred   |
| dev2          | 12    | A | AutoNorm ON        | Vol Ha      | andle:       | onap or r     | Free              | )      |
| distortion    | 100   | A | Load Model         |             |              |               |                   |        |
| fb1           | 1.38  | A |                    |             |              |               |                   |        |
| fb2           | 2     | A | Post Data          | Save        | Data         | Load Data     | Save Ma           | pper   |
| delModFreq    | 50    | A |                    |             |              |               |                   |        |
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|               |       |   | cavitymatrix layer | 0 cavity0 r | noquie FE    |               | Delet<br>Not Held | e<br>A |
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|            | 0: FBFM |       |   | 000                | ML M                     | apper          |             |          |
|------------|---------|-------|---|--------------------|--------------------------|----------------|-------------|----------|
| decimate1  |         | 20    | A | CREATE TRAININ     | G SET:                   |                |             |          |
| bitCrush1  |         | 10.53 | A | Audio Bus:         |                          | Params:        |             |          |
| decimate2  |         | 20000 | A | Add to Set         | Ran                      | dom            | Poisson     |          |
| bitCrush2  |         | 1     | A | =======            |                          | <br>`          |             |          |
| cfreq      |         | 20000 | A | TRAINING:          | TSNE Grid (2 dim         | <b>•</b>       |             |          |
| mfreq      |         | 20000 | A |                    | Usir                     | ig Audio Desc. | Irain       |          |
| dev1       |         | 10.7  | A | PEBEOBMING:        | Show Display             | Snan OFF       | Bus not Pre | d        |
| dev2       |         | 12    | A | AutoNorm ON        | Vol Handle:              |                | Free        | <u> </u> |
| distortion |         | 100   | A | Load Model         | ]                        | L              |             |          |
| fb1        |         | 1.38  | A | ======             | )<br>=================== |                |             |          |
| fb2        |         | 2     | A | Post Data          | Save Data                | Load Data      | Save Mappe  | ər       |
| delModFreq |         | 50    | A | =======            |                          | ~              |             |          |
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|            |         |       |   | OUTPUTS            |                          |                |             |          |
|            |         |       |   | cavityMatrix layer | 0 cavity0 module F       | BFM decimate1  | Delete      |          |
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| bitCrush1   | 10 | ).53 A | Audio Bus:  |  | Params:  |  |
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| tor Presets | 12 | 2 A    | AutoNorm ON   | Vol Handle:  | Shap Of I  | Free   |
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| fb1         | 1. | 38 A   |   |  |  |  |
| fb2         | 2  | A      | Post Data   | Save Data  | Load Data  | Save Mapp  |
| delModFreq  | 50 |        |   |  |  |  |
| not belo    |    |        | INPUTS  | Make   | Clear  |  |
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|             |    |        | OUTPUTS<br>cavityMatrix layer   | r0 cavity0 module FE   | 3FM decimate1  | Delete<br>Not Held A   |
|             |    |        | OUTPUTS<br>cavityMatrix layer   | r0 cavity0 module FE<br>r0 cavity0 module FE   | 3FM decimate1<br>0<br>3FM bitCrush1  | Delete<br>Not Held A<br>Delete   |
|             |    |        | OUTPUTS<br>cavityMatrix layer<br>cavityMatrix layer   | r0 cavity0 module FE<br>r0 cavity0 module FE   | 3FM decimate1<br>0<br>3FM bitCrush1<br>0   | Delete<br>Not Held A<br>Delete<br>Not Held A   |
|             |    |        | OUTPUTS<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer   | r0 cavity0 module FE<br>r0 cavity0 module FE<br>r0 cavity0 module FE                         | 3FM decimate1<br>0<br>3FM bitCrush1<br>0<br>3FM decimate2                            | Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete   |
|             |    |        | OUTPUTS<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer   | r0 cavity0 module FE<br>r0 cavity0 module FE   | 3FM decimate1<br>0<br>3FM bitCrush1<br>0<br>3FM decimate2<br>0                       | Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete<br>Not Held A                                   |
|             |    |        | OUTPUTS<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer                       | r0 cavity0 module FE<br>r0 cavity0 module FE<br>r0 cavity0 module FE                         | 3FM decimate1<br>0<br>3FM bitCrush1<br>0<br>3FM decimate2<br>0<br>3FM bitCrush2      | Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete                         |
|             |    |        | OUTPUTS<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer                       | r0 cavity0 module FE<br>r0 cavity0 module FE<br>r0 cavity0 module FE                         | 3FM decimate1<br>0<br>3FM bitCrush1<br>0<br>3FM decimate2<br>0<br>3FM bitCrush2      | Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete<br>Not Held A           |
|             |    |        | OUTPUTS<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer<br>cavityMatrix layer | r0 cavity0 module FE<br>r0 cavity0 module FE<br>r0 cavity0 module FE<br>r0 cavity0 module FE | 3FM decimate1<br>0<br>3FM bitCrush1<br>0<br>3FM decimate2<br>0<br>3FM bitCrush2<br>0 | Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete<br>Not Held A<br>Delete |

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|-----------------------|------------------|-------|---|---------------------|---------------------|-----------------|--------------|
|                       | decimate1        | 20    | Α | CREATE TRAININ      | G SET:              |                 |              |
|                       | bitCrush1        | 10.53 | A | Audio Bus:          |                     | Params:         |              |
|                       | decimate2        | 20000 | A | Add to Set          | Ran                 | dom             | Poisson      |
|                       | bitCrush2        | 1     | A |                     |                     |                 |              |
|                       | cfreq            | 20000 | A | TRAINING:           | TSNE Grid (2 dim    | )<br>Audie Dese | Train        |
|                       | mfreq            | 20000 | A |                     | Usin                | g Audio Desc.   | Irain        |
|                       | dev1             | 10.7  | A | PERFORMING          | Show Display        | Snap OFF        | Bus not Pred |
| ector Pr              | esets            | 12    | A | AutoNorm ON         | Vol Handle:         | Chap Chi        | Free         |
|                       | distortion       | 100   | A | Load Model          |                     |                 |              |
| $a = [x_0, x_1, x_2]$ | x fb1            | 1.38  | A |                     |                     |                 |              |
|                       | 2,, r.n-1<br>fb2 | 2     | A | Post Data           | Save Data           | Load Data       | Save Mappe   |
|                       | delModFreq       | 50    | A |                     |                     |                 |              |
|                       | not held         |       |   | INPUTS              | Make                | Clear           |              |
|                       |                  |       |   |                     |                     |                 |              |
|                       |                  |       |   | OUTPUTS             |                     |                 |              |
|                       |                  |       |   | cavityMatrix layer  | ) cavity0 module FI | 3FM decimate1   | Delete       |
|                       |                  |       |   |                     |                     | 0               | Not Held A   |
|                       |                  |       |   | cavityMatrix layer  |                     | BFM bitCrush1   | Delete       |
|                       |                  |       |   |                     |                     | 0               | Not Held A   |
|                       |                  |       |   | cavityMatrix layer  | ) cavity0 module F  | 3FM decimate2   | Delete       |
|                       |                  |       |   |                     |                     |                 | Not Heid A   |
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|                       |                  |       |   |                     |                     | 0               | Not Hold A   |

|   | U: FBFI                   | M |       |   |  |  |   |   |
|---|---------------------------|---|-------|---|--|--|---|---|
|   | decimate1                 |   | 20    | A | CREATE TRAINING  | SET:   |   |   |
|   | bitCrush1                 |   | 10.53 | A | Audio Bus:   |  | Params:   |   |
|   | decimate2                 |   | 20000 | A | Add to Set   | Ranc   | lom   | Poisson   |
|   | bitCrush2                 |   | 1     | A |  |  |   |   |
|   | cfreq                     |   | 20000 | A | TRAINING:  | I SNE Gria (2 dim)   | n Audio Doco  | Train   |
|   | mfreq                     |   | 20000 | A |  |  |   | ITain   |
|   | dev1                      |   | 10.7  | Α | PERFORMING:  | Show Display   | Snap OFF  | Bus not Pred  |
| <u>ector Pr</u>                                 | esets                     |   | 12    | Α | AutoNorm ON  | Vol Handle:  |   | Free  |
|   | distortion                |   | 100   | Α | Load Model   |  |   |   |
| $= \begin{bmatrix} x_0, x_1, x_2 \end{bmatrix}$ | , X fb1                   |   | 1.38  | A |  |  |   |   |
|   | fb2                       |   | 2     | Α | Post Data  | Save Data  | Load Data   | Save Mappe  |
| $= \begin{bmatrix} x & x & x \end{bmatrix}$     | delModFreq                |   | 50    | A |  |  |   |   |
|   | 2 <sup>n-1</sup> not held |   | A     |   | INPUTS   | Make   | Clear   |   |
|   |                           |   |       |   |  |  |   |   |
|   |                           |   |       |   | OUTPUTS  |  |   |   |
|   |                           |   |       |   | cavityMatrix layer0  | cavity0 module FE  | 3FM decimate1   |   |
|   |                           |   |       |   |  |  |   | Delete  |
|   |                           |   |       |   |  |  | 0   | Delete Not Held A   |
|   |                           |   |       |   | cavityMatrix layer0  |  | 0<br>3FM bitCrush1  | Delete Not Held A Delete  |
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|   |                           |   |       |   | cavityMatrix layer0<br>cavityMatrix layer0   | cavity0 module FE  | 0<br>3FM bitCrush1<br>0<br>3FM decimate2                            | Delete Not Held A Delete Not Held A Delete Uot Held A   |
|   |                           |   |       |   | cavityMatrix layer0  | cavity0 module FE  | 0<br>BFM bitCrush1<br>0<br>BFM decimate2<br>0                       | Delete Not Held A Delete Not Held A Delete Iot Held A Delete Iot Held A                                     |
|   |                           |   |       |   | cavityMatrix layer0<br>cavityMatrix layer0<br>cavityMatrix layer0                        | cavity0 module FE<br>cavity0 module FE<br>cavity0 module FE                      | 0<br>3FM bitCrush1<br>0<br>3FM decimate2<br>0<br>3FM bitCrush2      | Delete Not Held A                   |
|   |                           |   |       |   | cavityMatrix layer0<br>cavityMatrix layer0<br>cavityMatrix layer0                        | cavity0 module FE<br>cavity0 module FE<br>cavity0 module FE                      | 0<br>SFM bitCrush1<br>0<br>SFM decimate2<br>0<br>SFM bitCrush2<br>0 | Delete Not Held A |
|   |                           |   |       |   | cavityMatrix layer0<br>cavityMatrix layer0<br>cavityMatrix layer0<br>cavityMatrix layer0 | cavity0 module FE<br>cavity0 module FE<br>cavity0 module FE<br>cavity0 module FE | 0<br>SFM bitCrush1<br>0<br>SFM decimate2<br>0<br>SFM bitCrush2<br>0 | Delete Not Held A |

|  |                 | 0: FBFM |    |       |   |                                   |                     |                 |              |
|--|-----------------|---------|----|-------|---|-----------------------------------|---------------------|-----------------|--------------|
|  | decimate1       |         | 2  | 20    | A | CREATE TRAININ                    | G SET:              |                 |              |
|  | bitCrush1       |         | 1  | 0.53  | A | Audio Bus:                        |                     | Params:         |              |
|  | decimate2       |         |    | 20000 | A | Add to Set                        | Ran                 | dom             | Poisson      |
|  | bitCrush2       |         | 1  |       | A |                                   |                     |                 |              |
|  | cfreq           |         |    | 20000 | A | TRAINING:                         | I SNE Grid (2 dim   | )<br>Audio Dece | Turin        |
|  | mfreq           |         |    | 20000 | A |                                   | Usin                | g Audio Desc.   | Irain        |
|  | dev1            |         |    | 0.7   | A | PERFORMING:                       | Show Display        | Snap OFF        | Bus not Pred |
| /ector Pr  | esets           |         | 1  | 2     | A | AutoNorm ON                       | Vol Handle:         |                 | Free         |
|  | distortion      |         | 1  | 00    | A | Load Model                        |                     |                 |              |
| $a = [x_0, x_0, x_0]$  |                 |         | 1  | .38   | A |                                   | ,                   |                 |              |
| L ()' 1' 2   | 2' n-1 J<br>fb2 |         | 12 | 2     | A | Post Data                         | Save Data           | Load Data       | Save Mappe   |
| $\mathbf{x} = \begin{bmatrix} \mathbf{x} & \mathbf{x} \end{bmatrix}$ | delModFreq      |         | T  | 50    | A |                                   |                     |                 |              |
| $J = [\Lambda_0, \Lambda_1, \Lambda_2]$                              | 2, n-1 1        | eld     |    | A     |   | INPUTS                            | Make                | Clear           |              |
|  |                 |         |    |       |   |                                   |                     |                 |              |
|  |                 |         |    |       |   | OUTPUTS                           |                     |                 |              |
|  |                 |         |    |       |   | cavityMatrix layer                | 0 cavity0 module F  | BFM decimate1   | Delete       |
|  |                 |         |    |       |   |                                   |                     | 0               | Not Held A   |
|  |                 |         |    |       |   | cavityMatrix layer                |                     |                 | Delete       |
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|  |                 |         |    |       |   |                                   |                     | 9               | INNEHEID A   |
|  |                 |         |    |       |   | a public di districci di successi |                     |                 |              |
|  |                 |         |    |       |   | cavityMatrix layer                | 0 cavity0 module F  | BFM ctreq       | Delete       |



 $\begin{aligned} & \text{Vector Presets} \\ \text{a} = [x_0, x_1, x_2, \dots x_{n-1}] \\ \text{b} = [x_0, x_1, x_2, \dots x_{n-1}] \\ \text{c} = [x_0, x_1, x_2, \dots x_{n-1}] \\ \text{d} = [x_0, x_1, x_2, \dots x_{n-1}] \end{aligned}$ 



 $\begin{aligned} & \mathsf{Vector \ Presets} \\ & \mathsf{a} = [x_0, x_1, x_2, \dots x_{n-1}] \\ & \mathsf{b} = [x_0, x_1, x_2, \dots x_{n-1}] \\ & \mathsf{c} = [x_0, x_1, x_2, \dots x_{n-1}] \\ & \mathsf{d} = [x_0, x_1, x_2, \dots x_{n-1}] \end{aligned}$ 

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## TSNE

- t-Distributed Stochastic Neighbor Embedding
- Dimensionality Reduction Algorithm
- Vectors that are similar in high dimensional space are embedded near each other in low dimensional space, while vectors dissimilar in high dimensional space are embedded far away in low dimensional space



```
1 //https://github.com/karpathy/tsnejs/blob/master/tsne.js
 2
 3 // create main global object
 4 TSNE {
 5
       var /*return_v,
 6
       v_val,*/
 7
       iter,
 8
       perplexity,
 9
       dim,
10
       epsilon,
       sizeOfDataSet,
11
12
       <y,
13
       gains,
14
       ystep;
15
16
       *new {
17
           arg perplexity = 30, dim = 2, epsilon = 10;
18
           ^super.new.init(perplexity, dim, epsilon);
       }
19
20
21
       init {
22
           arg perplexity_ = 30, dim_ = 2, epsilon_ = 10;
23
24
           perplexity = perplexity_; // effective number of nearest neighbors
           dim = dim_; // by default 2-D tSNE
25
           ensilon = ensilon \cdot // learning rate
26
```









# Munkres Algorithm

- aka "Hungarian Algorithm" or "Kuhn-Munkres Algorithm"
- Optimal solution to linear assignment problem
- Every element in the **t-SNE embeddings** must be assigned to one unique element in the **grid of locations**





#### t-SNE / Munkres demo



#### **User-Defined (no stochasticity)** <u>Sampling</u> <u>Dimensionality</u> Generate Transformation <u>Samples</u> <u>Strategy</u> Synthesis Params Latent Synthesis Space Params ))) Audio User t-SNE / Selected Descriptors Munkres



## t-SNE / Munkres demo 2



#### Benefits of TSNE / Munkres approach

- Preserves user-defined presets
- TSNE recognized as superior dimensionality reduction
- Munkres finds optimal solution
- "Non-linear" latent space requires practice to learn



## Rejected Alternatives

- Neural Network supervised learning requires knowing the desired low dimensional structure before training
  - Neural Networks generally need a lot of data
- Self-Organizing Maps doesn't guarantee that exact userdefined presets are preserved



#### Reflections



interpolated



gestural

#### musical ? more practice needed





#### Indexical Control Symbolic Control

Interface maps to The instrument

Mapping is arbitrary



## Learned Synthesis Parameters







## Poisson Disk Sampling





Uniform Distribution





Distribution





Distribution























#### demo 3



#### the Future

- More control strategies
- More practice performing
- Find more appropriate sound generators
- More audio descriptor options
- Neural Network learn modular synth
  - for live audio input mimicry
  - for gestural control



## Thank you. Questions?



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