香港中文大學（深圳）
The Chinese University of Hong Kong, Shenzhen

Structure-Enhanced Pop Music Generation via Harmony-Aware Learning

Xueyao Zhang[1,2], *Jinchao Zhang*[2], *Yao Qiu*[2], *Li Wang*[2,3], *Jie Zhou*[2]

[1] The Chinese University of Hong Kong, Shenzhen, China
[2] Pattern Recognition Center, WeChat AI, Tencent Inc, China
[3] Communication University of China

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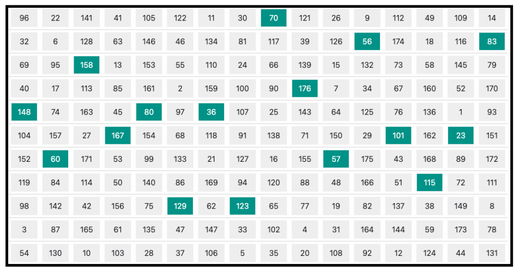
Background: Symbolic Music Generation

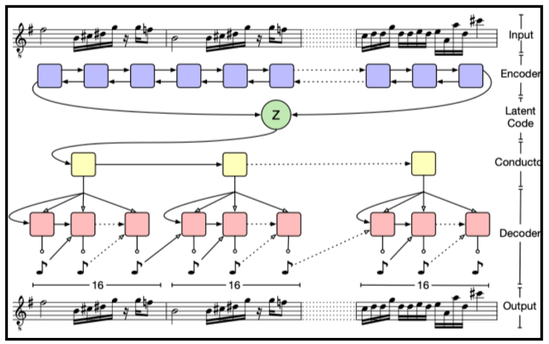
- Also known as: **algorithmic composition**, **automatic music creation**

Mozart Dice Game (18th century)

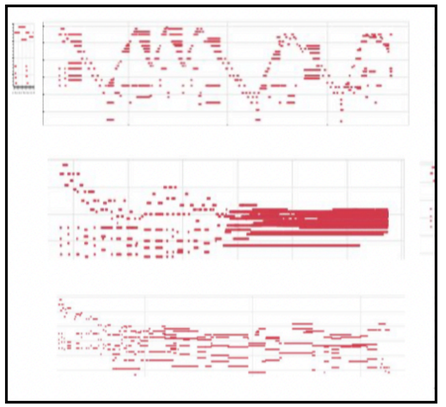


96	22	141	41	105	122	11	30	70	121	26	9	112	49	109	14
32	6	128	63	146	46	134	81	117	39	126	56	174	18	116	83
69	95	158	13	153	55	110	24	66	139	15	132	73	58	145	79
40	17	113	85	161	2	159	100	90	176	7	34	67	160	52	170
148	74	163	45	80	97	36	107	25	143	64	125	76	136	1	93
104	157	27	167	154	68	118	91	138	71	150	29	101	162	23	151
152	60	171	53	99	133	21	127	16	155	57	175	43	168	89	172
119	84	114	50	140	86	169	94	120	88	48	166	51	115	72	111
98	142	42	156	75	129	62	123	65	77	19	82	137	38	149	8
3	87	165	61	135	47	147	33	102	4	31	164	144	59	173	78
54	130	10	103	28	37	106	5	35	20	108	92	12	124	44	131

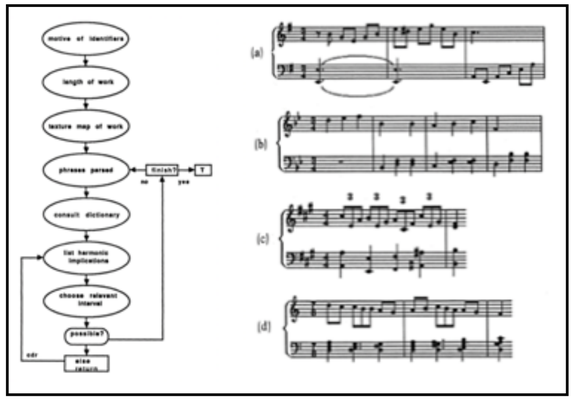
MusicVAE (ICML'18)



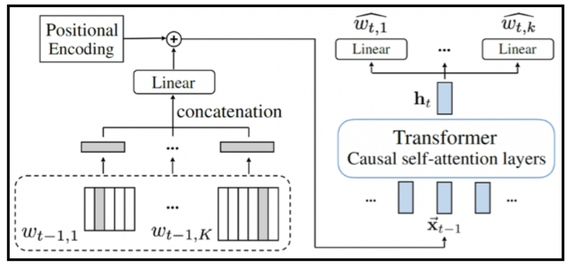
Music Transformer (ICLR'19)



EMI (Computer Music Journal, 1987)



CP-Transformer (AAAI'21)



Rule-based music generation

Data-driven music generation

Composing music with a satisfactory structure is still challenging!

- **What is structure?**
  - **Form**: The **temporal** relationship and dependency among the music.
  - **Texture**: The **spatial** relationship and the organized way between the multiple parts or instruments of music.

Composing music with a satisfactory structure is still challenging!

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- **Why is structure hard to model?**

① It depends largely on the musical **context**.

② It exists in various musical elements and appears the **hierarchy**.

③ **Form and texture** connect closely and support to each other.

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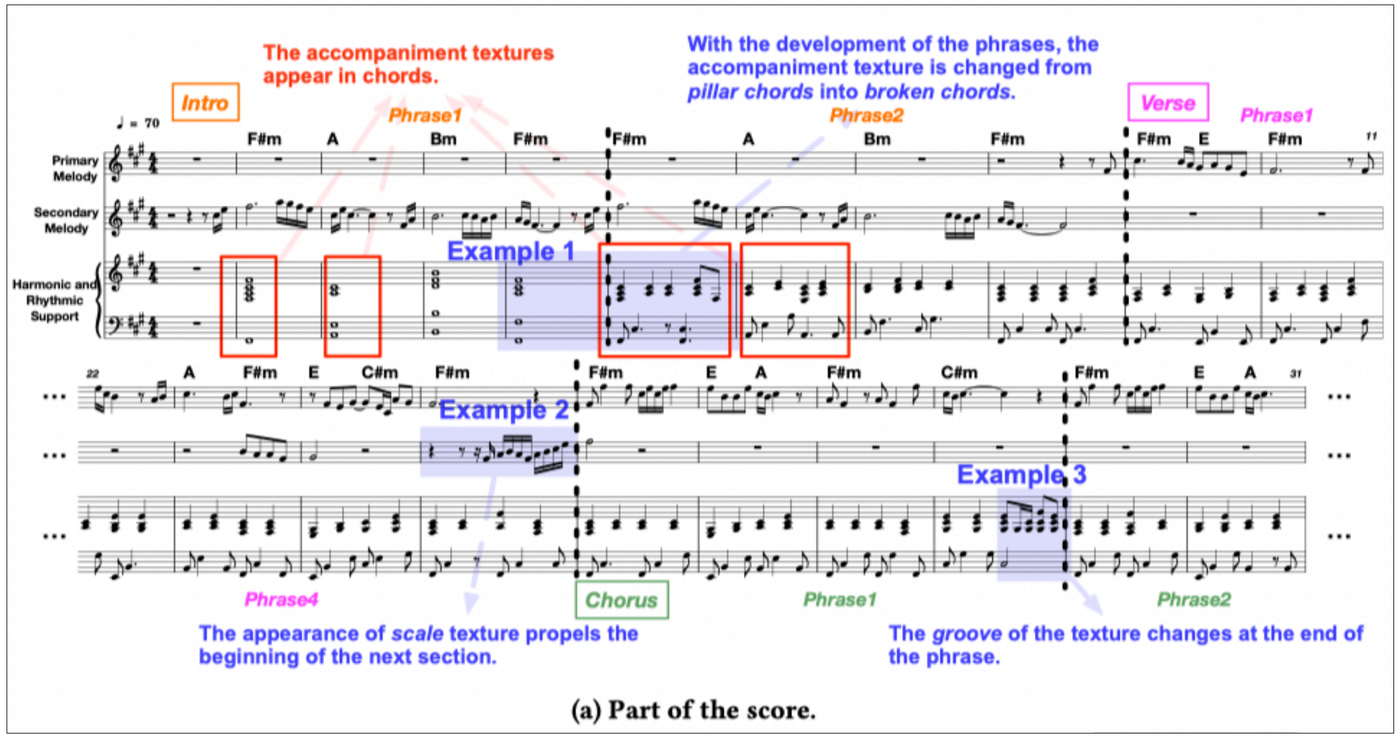
③ **Form and texture** connect closely and support to each other.

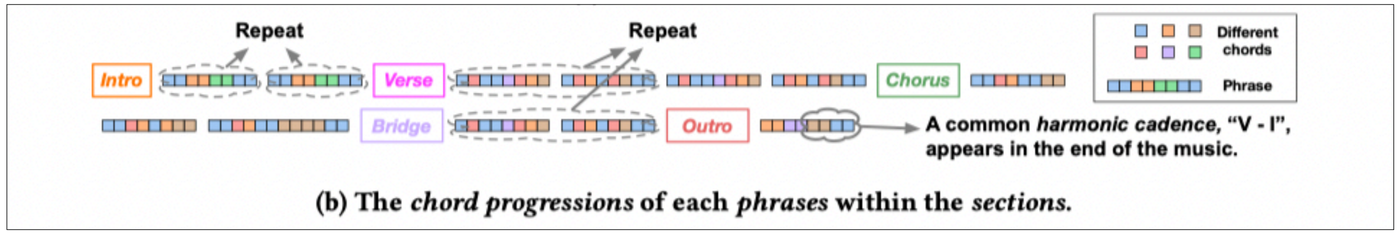
Three corresponding requirements

- ① → To mine the musical contexts adaptively
- ② → To model the hierarchy of multi-level elements
- ③ → To capture such mutual dependency

Motivation: A strong connection between *harmony* and structure

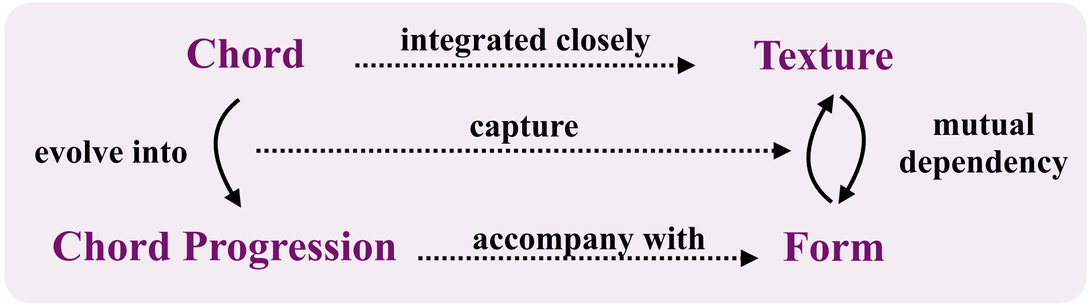


(a) Part of the score.



(b) The *chord progressions* of each *phrases* within the *sections*.

Information Flow



Harmony **Structure**

Methodology (1/3): How to represent the symbolic music?

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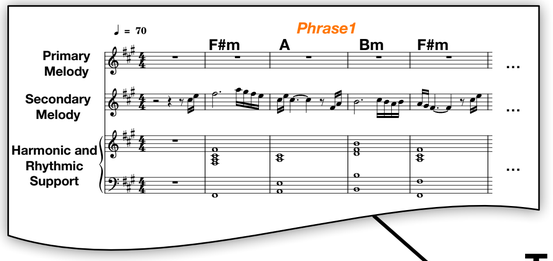
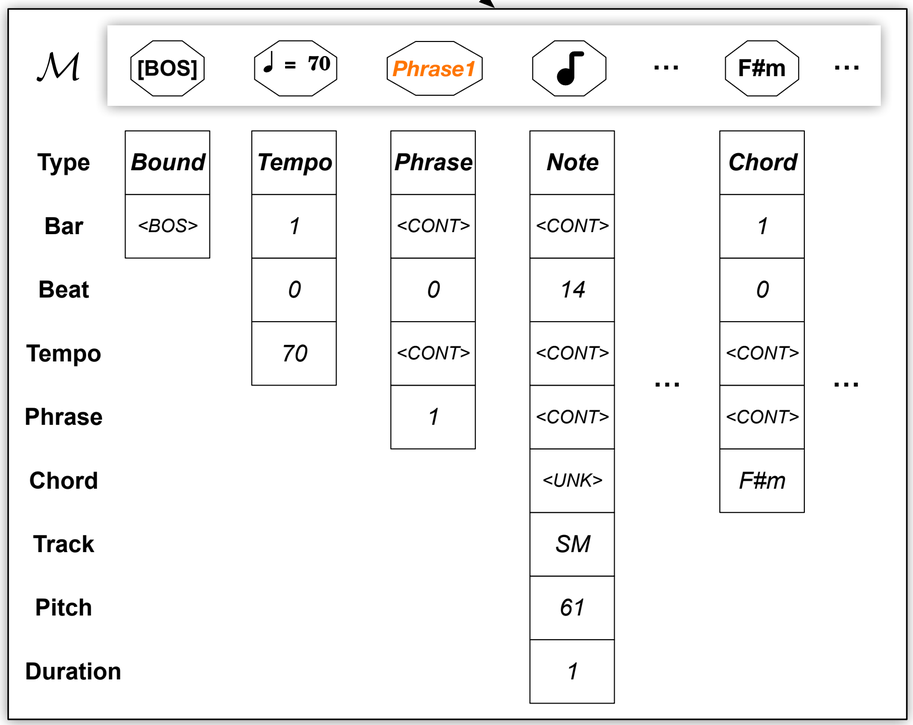


Solution: **To serialize the multi-type musical information**

Tokenize the score



Level	Event	Description
Token type	Type	The type of the token
Metrical	Bar	The bar position of the token
	Beat	The beat position in a bar of the token
	Tempo	The tempo of the token
Structure	Phrase	The phrase that the token belongs with
	Chord	The chord that the token belongs with
Note	Track	The track (or the instrument) of the token
	Pitch	The pitch of the token
	Duraion	The duration time of the token

Nine events in music tokenization

Methodology (2/3): How to model the hierarchy of structure?

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Solution: To design the hierarchical interaction

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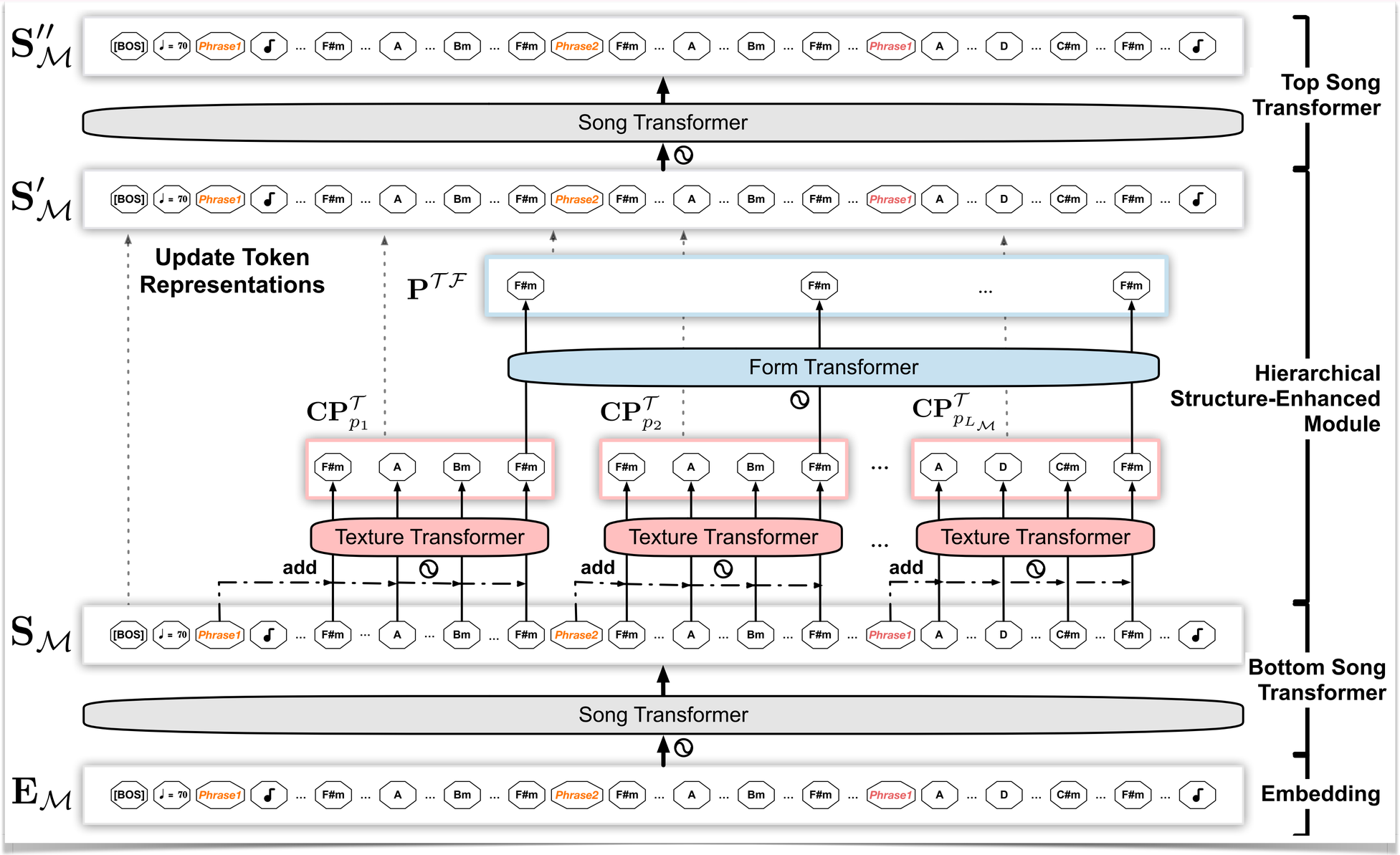

Methodology (3/3): How to capture the dependency between *form* and *texture*?

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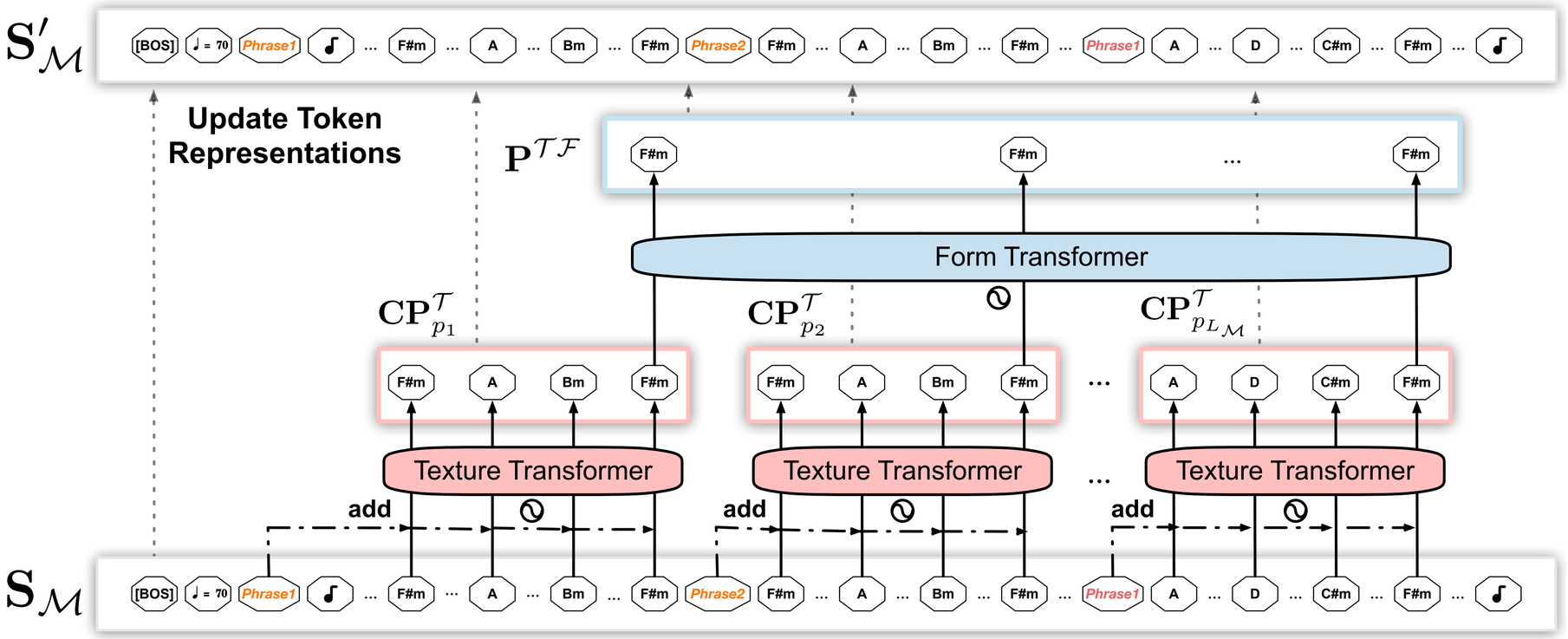
Solution: **To learn the dependency from *local texture* to *global form***

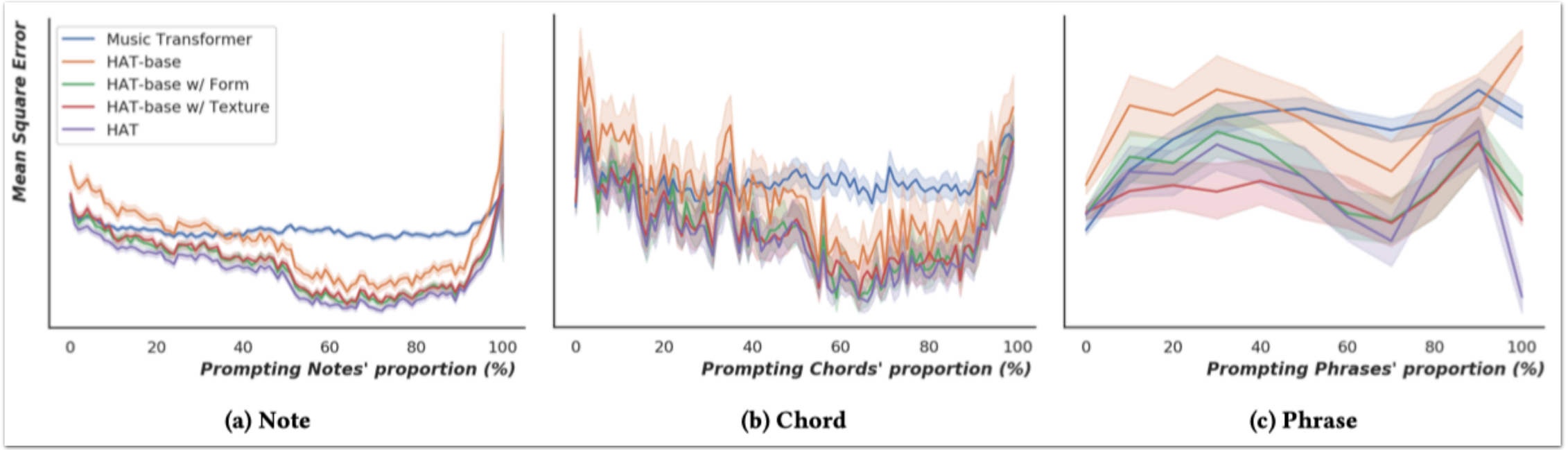


Evaluation (1/2): Performance of Music Understanding

Next Token Prediction (NTP)

Model	Accuracy				Mean Square Error (↓)			
	Note	Chord	Phrase	Avg.	Note	Chord	Phrase	Avg.
CP-Transformer [12]	0.406	0.368	-	0.387	0.132	0.135	-	0.134
Music Transformer [13]	*0.587*	0.488	0.256	0.444	*0.078*	0.084	0.121	0.094
HAT-base	0.485	0.417	0.228	0.377	0.099	0.099	0.124	0.107
HAT-base w/ Form	0.564	0.500	*0.309*	*0.458*	0.082	*0.082*	**0.116**	*0.093*
HAT-base w/ Texture	0.571	*0.503*	0.268	0.447	0.081	0.084	0.122	0.096
HAT	**0.594**	**0.518**	**0.323**	**0.478**	**0.076**	**0.080**	**0.116**	**0.090**

The trends of the NTP's Mean Square Error as the prompts' lengths increase.



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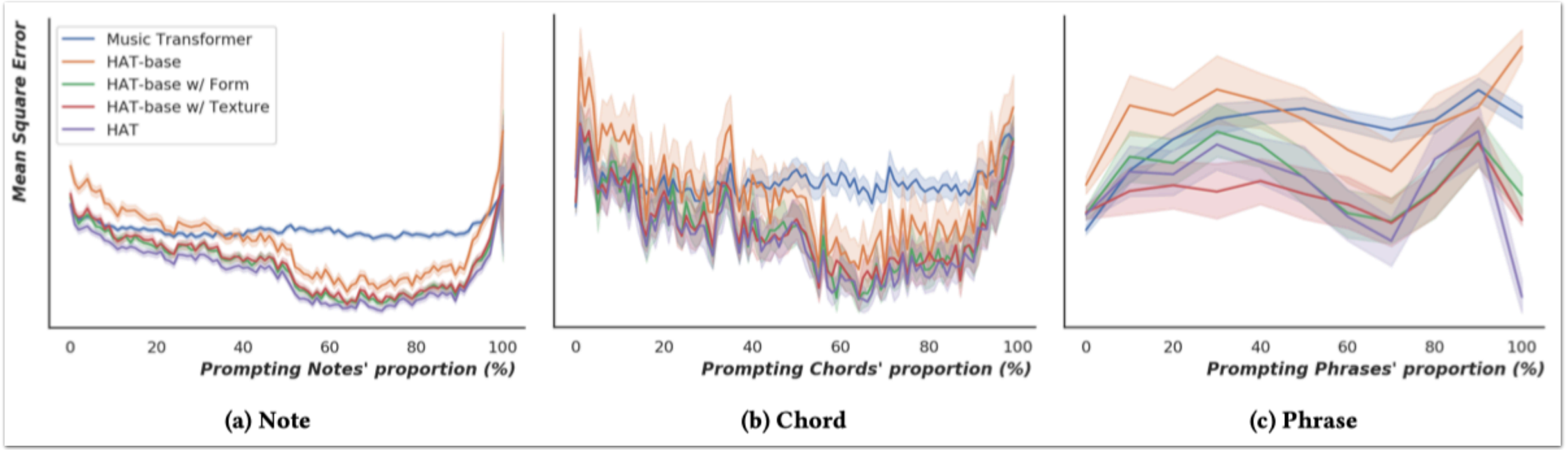

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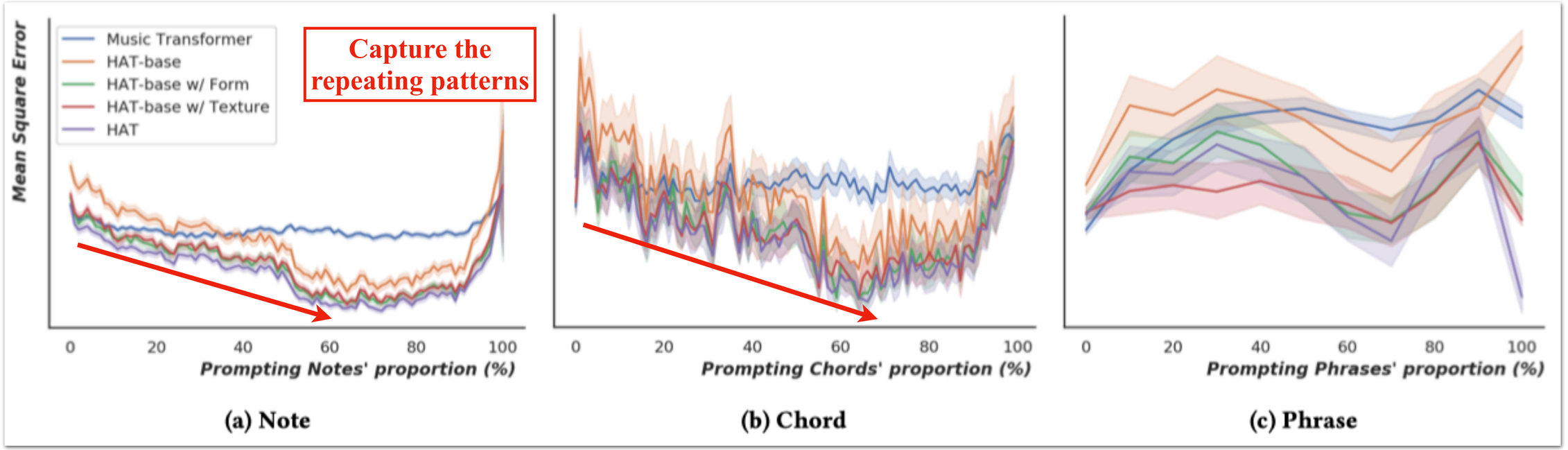

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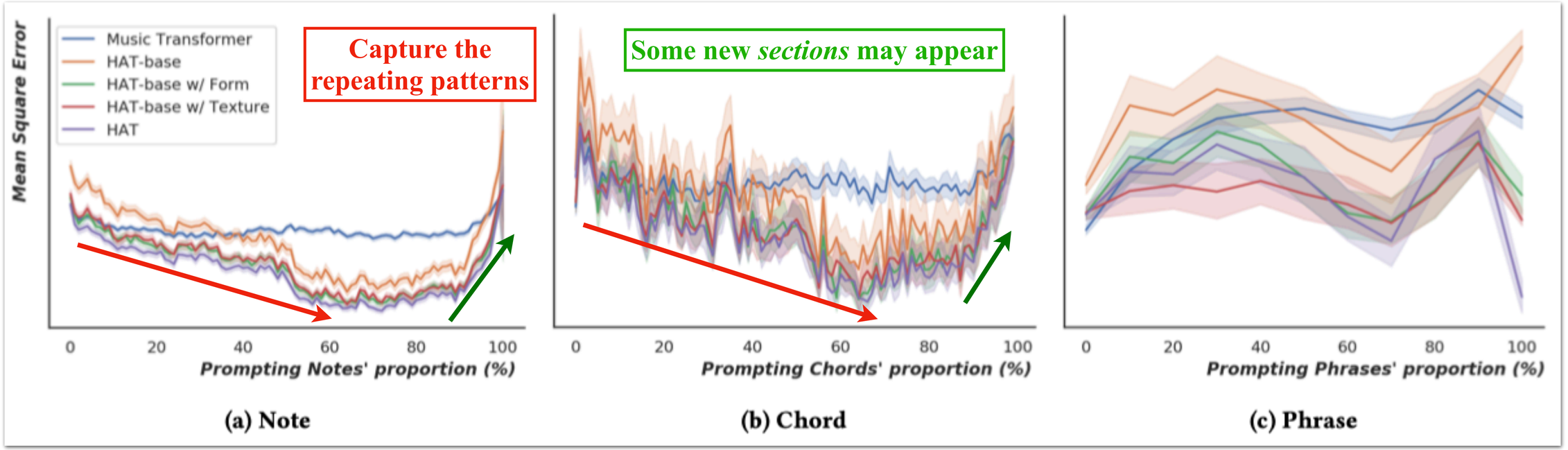

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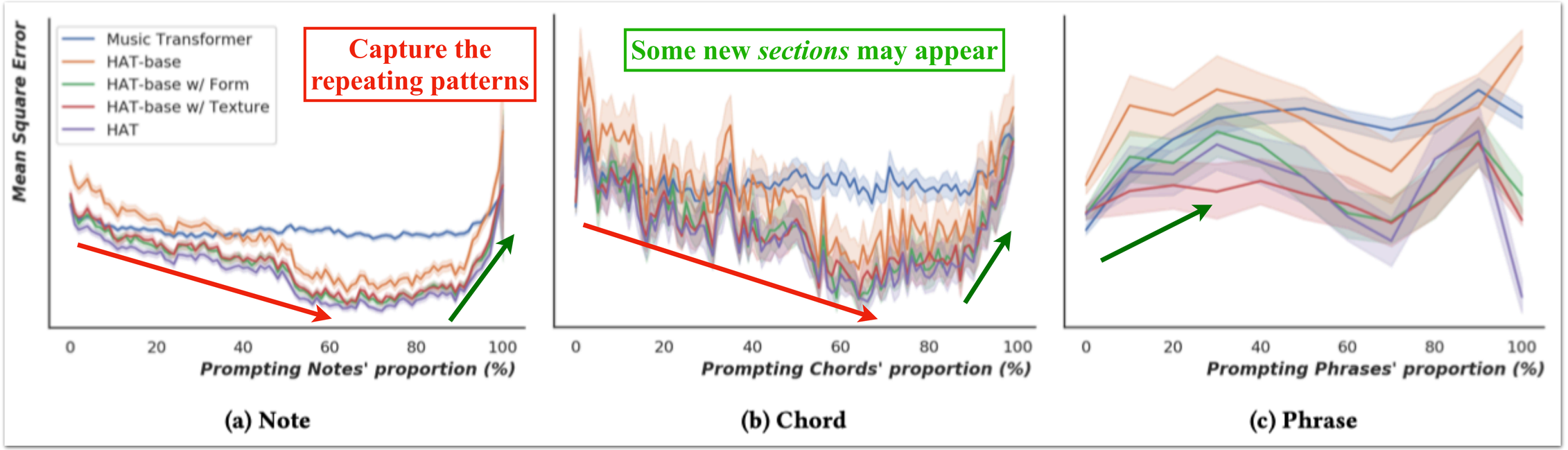

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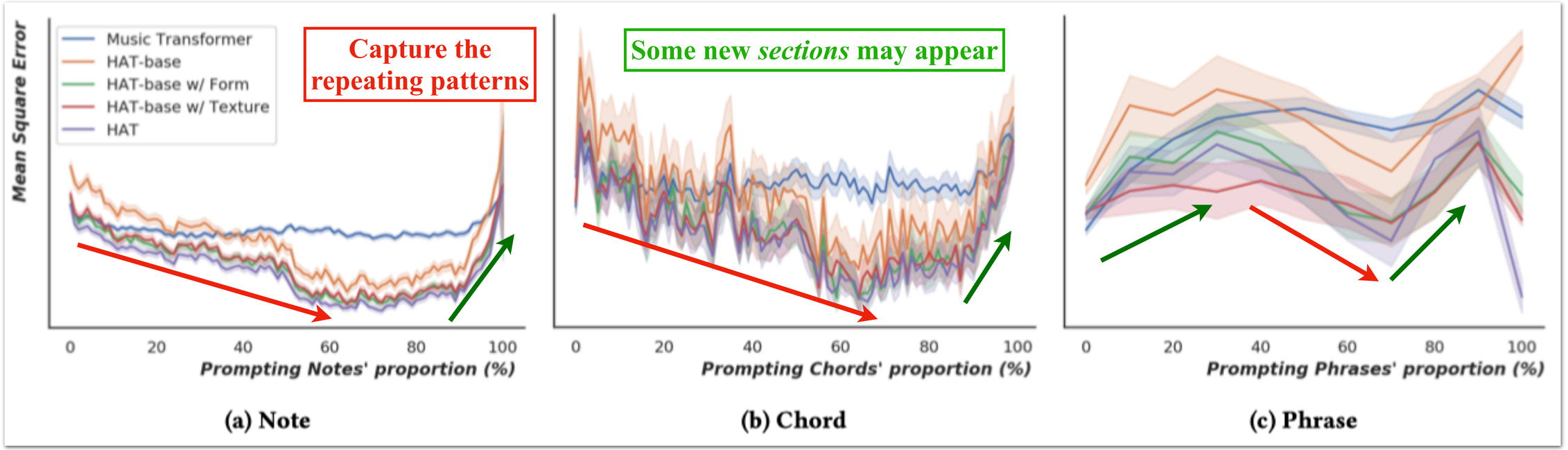

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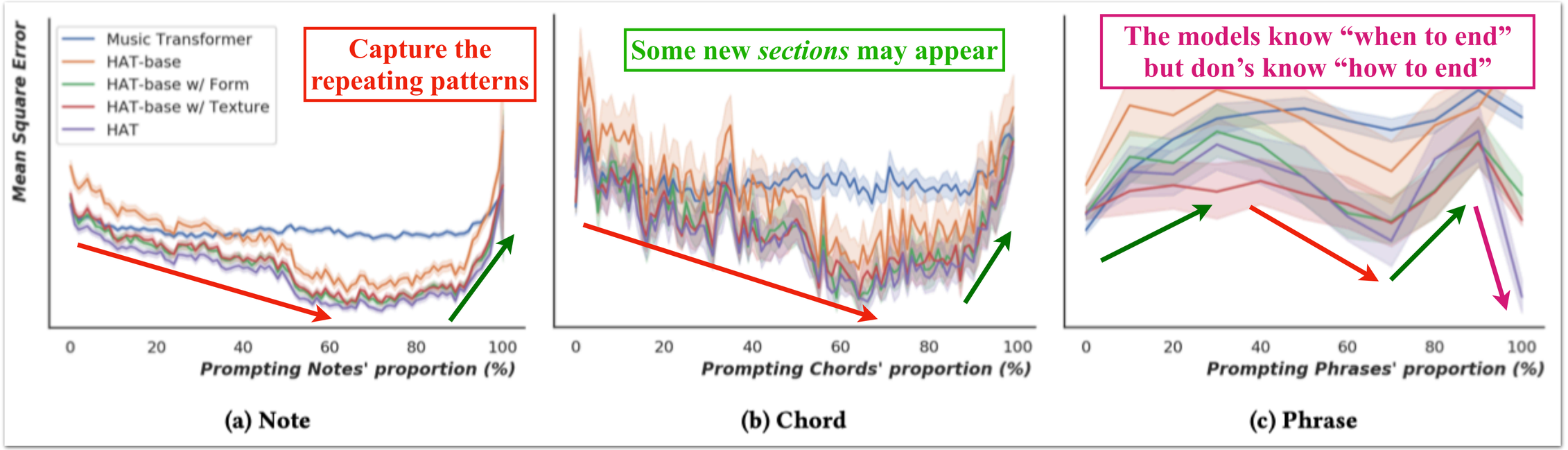


Evaluation (2/2): Performance of Music Generation

- **Two objective metrics (newly proposed)**

Accompaniment Groove Stability (AGS)

To measure **the stability of grooves** between accompaniment textures.

Chord Progression Realism (CPR)

To evaluate both **irregularity** and **variation rationality** of the **chord progressions**.

Model	Texture	Form		
	AGS	CPR		
		2-grams	3-grams	4-grams
Real	0.572	0.504	0.564	0.551
CP-Transformer [12]	0.193	0.312	0.250	0.132
Music Transformer [13]	0.256	0.413	0.384	0.267
HAT-base	0.382	0.403	0.369	0.264
HAT-base w/ Form	0.422	*0.439*	*0.421*	0.307
HAT-base w/ Texture	*0.456*	0.434	0.417	*0.310*
HAT	**0.474**	**0.447**	**0.435**	**0.320**

Objective Evaluation

- **Six Subjective metrics**

Overall Performance (OP)

To score **Melody** (M) and **Groove** (G)

Texture

To score **Primary Melody** (PM) and **Consonance** (CO)

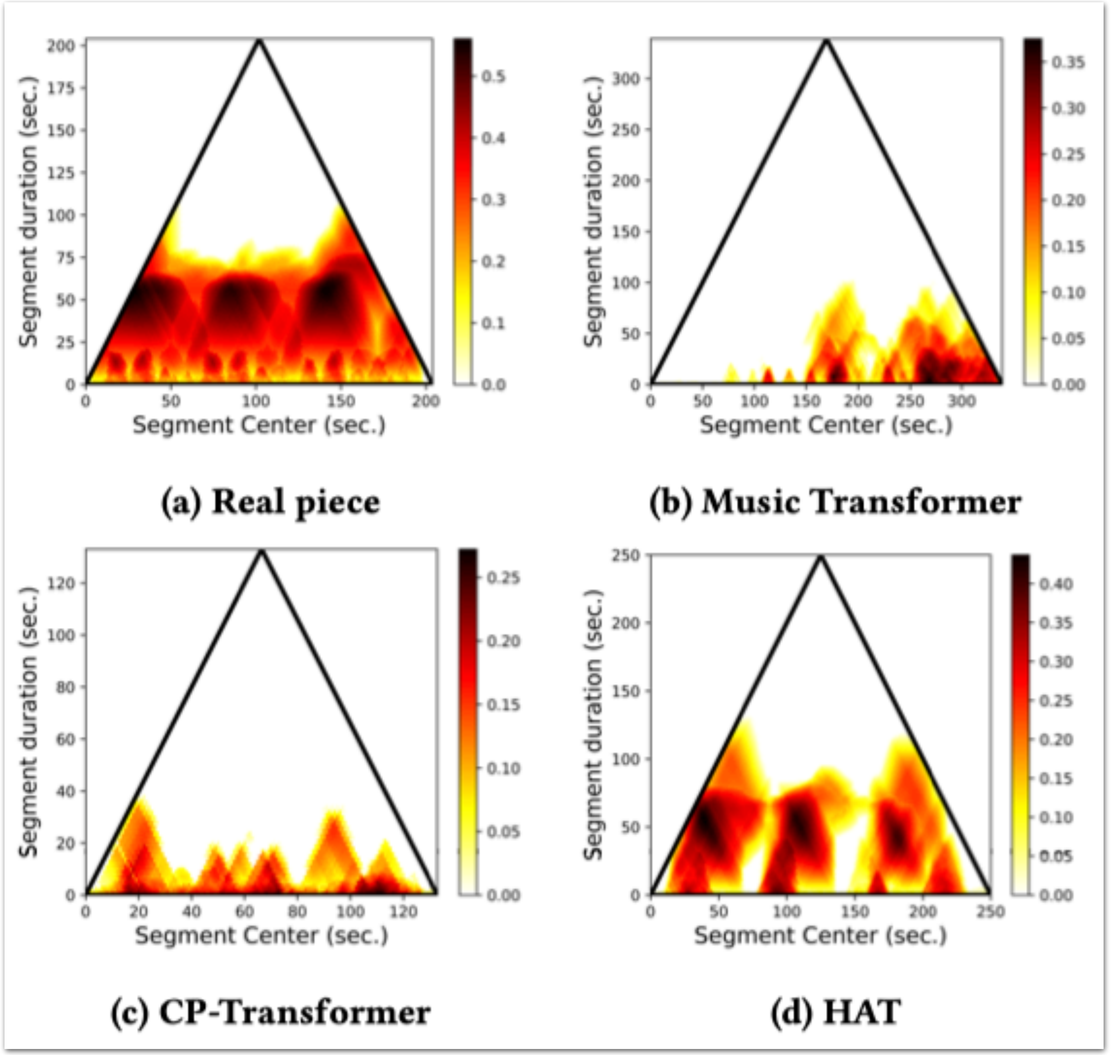
Form

To score **Coherence** (C) and **Integrity** (I)

Model	OP		Texture		Form		Avg.
	M	G	PM	CO	C	I	
CP-Transformer [12]	0.356	0.356	0.385	0.403	0.419	0.380	0.383
Music Transformer [13]	0.417	0.375	**0.700**	0.562	0.550	0.375	0.496
HAT-base	0.267	*0.550*	*0.680*	0.400	0.400	0.450	0.458
HAT-base w/ Form	**0.638**	0.504	0.511	*0.641*	*0.557*	*0.574*	*0.571*
HAT-base w/ Texture	0.436	0.477	0.514	0.539	0.538	0.504	0.501
HAT	*0.592*	**0.552**	0.598	**0.661**	**0.585**	**0.618**	**0.601**

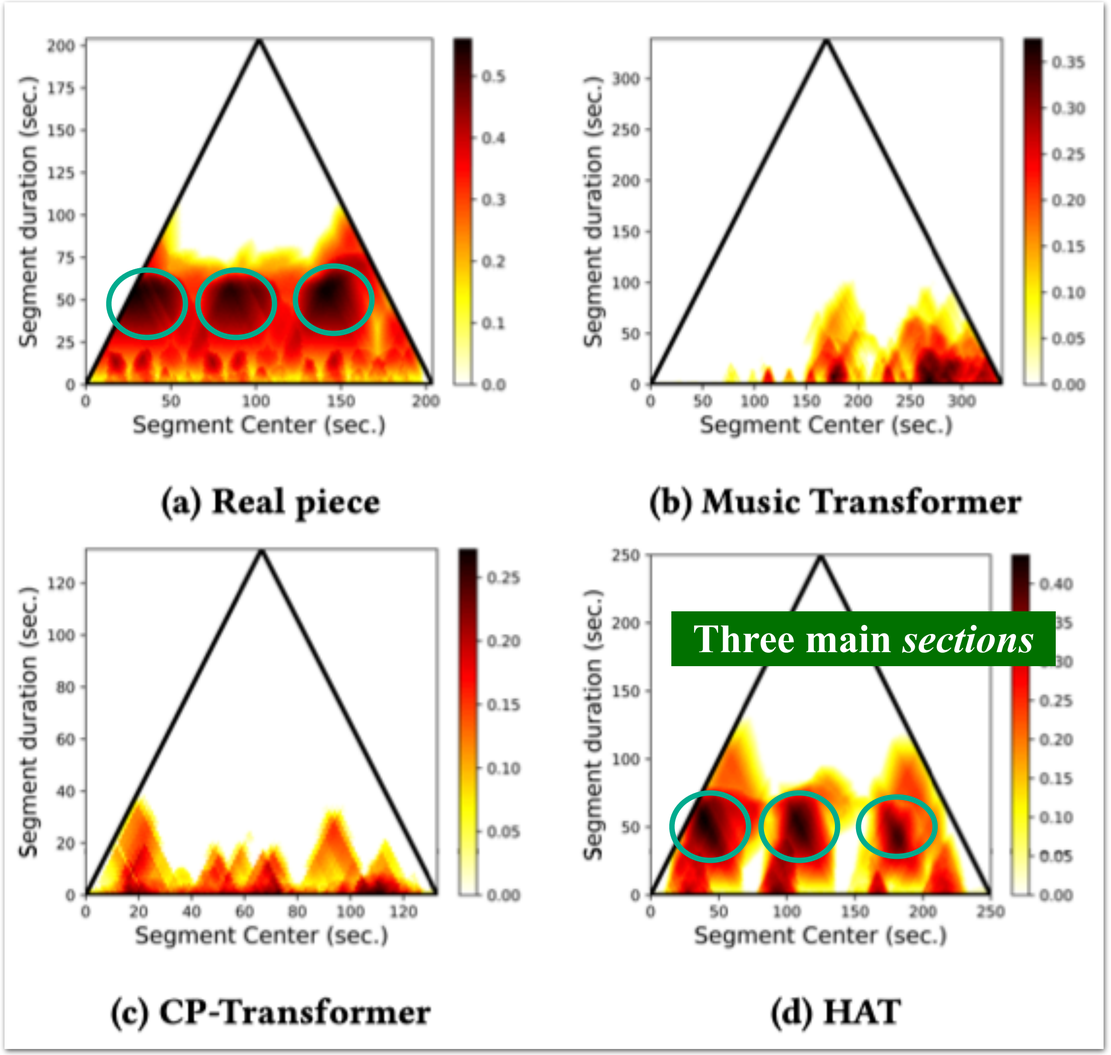
Subjective Evaluation

Case Study



Fitness scape plots. The generated pieces are prompted by the *intro* of the real piece.

Case Study



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😊 HAT has been capable of **imitating the outline structure** of the real music.

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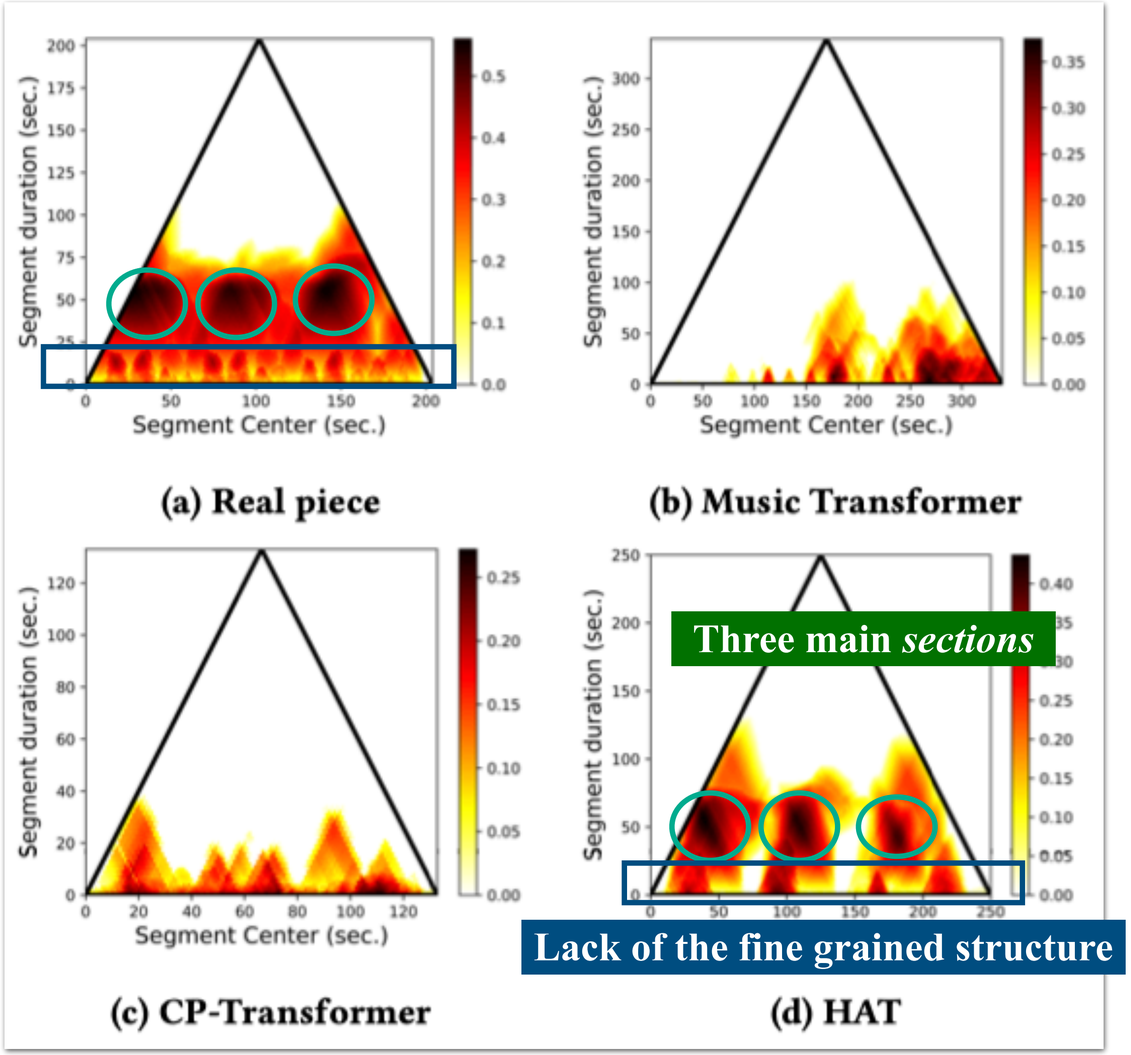

Fitness scape plots. The generated pieces are prompted by the *intro* of the real piece.

😊 HAT has been capable of **imitating the outline structure** of the real music.

😫 It is still too hard for HAT to **polish and refine** the generated pieces to pursue a real work of art.

Conclusion and Future work

- **Contributions**
  - We propose the **harmony-aware learning** for structure-enhanced pop music generation.
  - We design the **hierarchical structured-enhanced mechanism** to bridge form and texture.
  - We develop **two objective metrics** for evaluating the structure of music from the perspective of the harmony.
- **Future work**
  - **Controllable Generation**: Eg: explore new methods (or controllable modules) to polish and refine the musical details of generated pieces.
  - **Symbolic to Audio (Performance Synthesis)**: Research on merging the human performance techniques into the generated music.

THANKS

Xueyao Zhang (张雪遥)

First-year PhD student,
School of Data Science, The Chinese University of Hong Kong, Shenzhen

Email: xueyaozhang@link.cuhk.edu.cn
Homepage: https://www.zhangxueyao.com/

Research interest: **“AI + Music”**, especially on:

- ✦ **Singing Voice Synthesis**
- ✦ **Algorithmic Composition**

Code: https://github.com/RMSnow/HAT
Demo: https://www.zhangxueyao.com/data/HAT/demo.html

香港中文大學(深圳)
The Chinese University of Hong Kong, Shenzhen