Optimization of Pressure Acoustic Simulation by Generative CNN Model

Qian Shi

M.E. Rinker, Sr. School of Construction Management

Chair: Prof. Ian Flood
Co-Chair: Prof. Hassan Azad
Member: Chaofeng Wang
Member: Kejun Huang

2024/10/28

1 Background

2 Literature Review

3 Methodology

4 Experiment

5 Contribution

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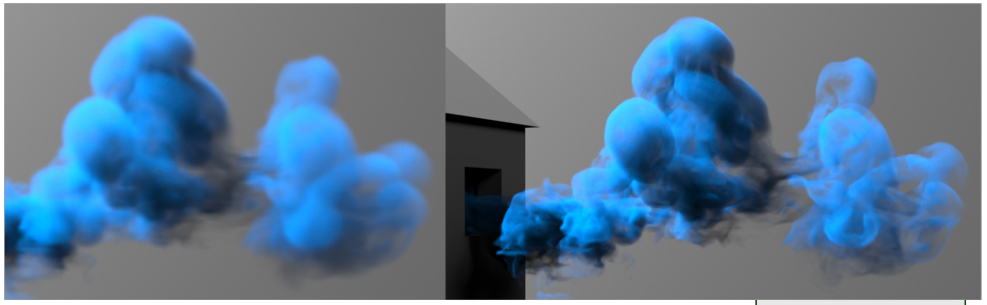
Background

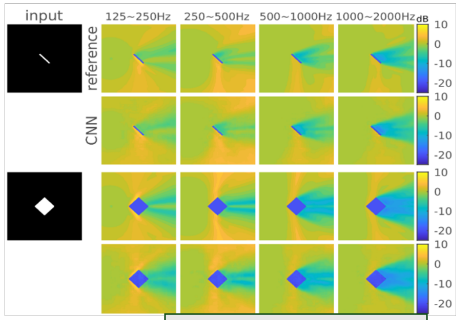
- Challenges

❖ Physically-based Simulation Are Still Slow

- Obtain High-quality Results Is Computationally Expensive



(Xie et al., 2018)



(Fan et al., 2015)

❖ Limited Support For Follow-up Operation

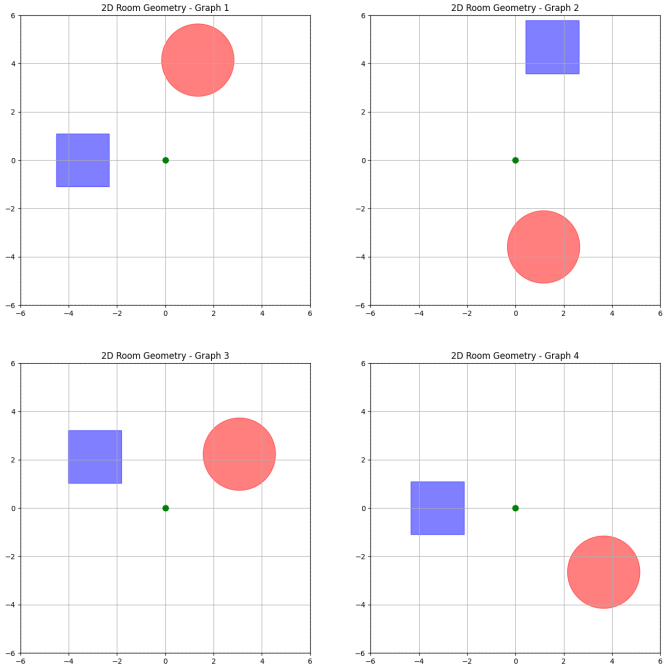
- Changing An Existing Simulation Entails Error

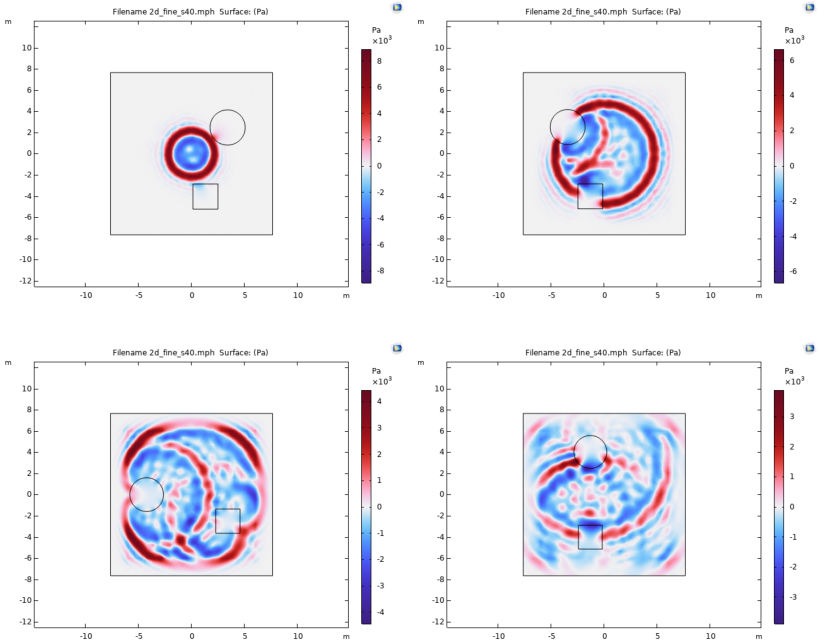
❖ Producing Data Consumes Large Amount Of Storage Space

- Growing Need To Reuse Stored Simulation Fata

Background

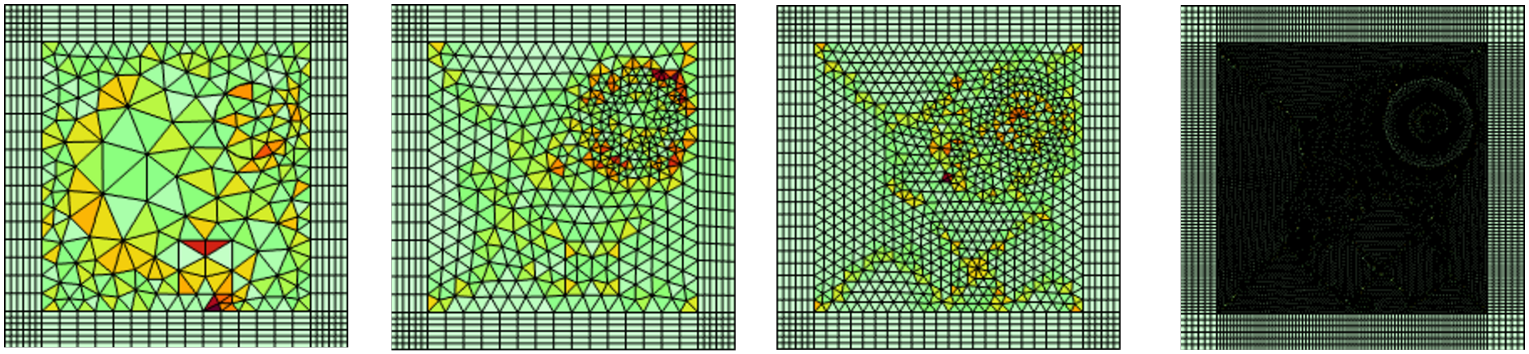
- Problem Statement





Background

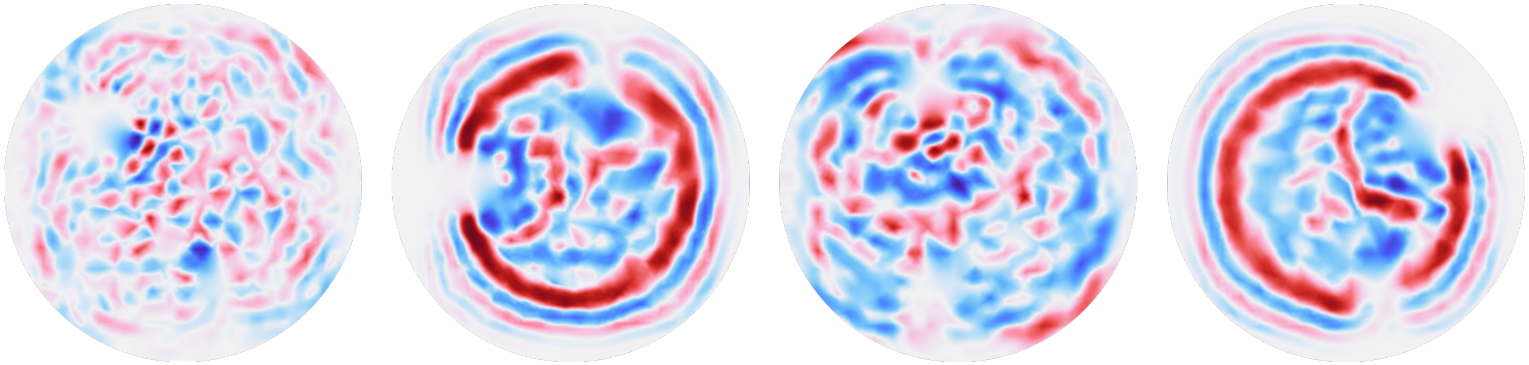
- Spatial Consideration



DOF:5000 DOF:7000 DOF:10000 DOF:22000

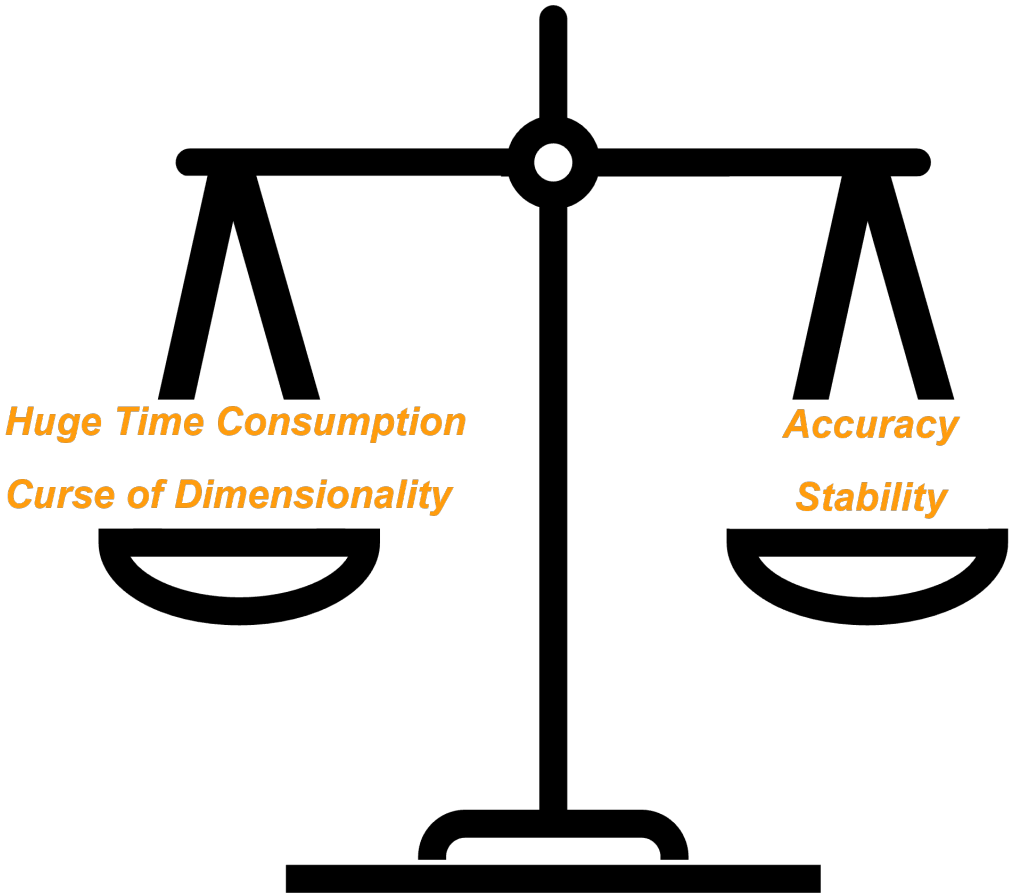
Background

- Temporal Consideration



Background

- Problem Statement



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Literature Review

- Chronology

FEM — *Alexander Hrennikoff* — **1941**

FDTD — *K. S. Yee* — **1966**

Ray tracing — *Arthur Appel* — **1968**

BEM — *Brebbia* — **1978**

Radiosity — *Goral et al.*

Beam tracing — *P. S. Heckbert and P. Hanrahan* — **1984**

Corse-grain model — *Ian Flood* — **2007**

Conv-LSTM — *Shi, Xingjian, et al.* — **2015**

PredRNN — *Wang, Yunbo, et al.* — **2017**

Latent space integrated method — *Kim et al.* — **2019**

TI to video — *Ni, Haomiao, et al.* — **2024**

Literature Review

- Coarse-grain model

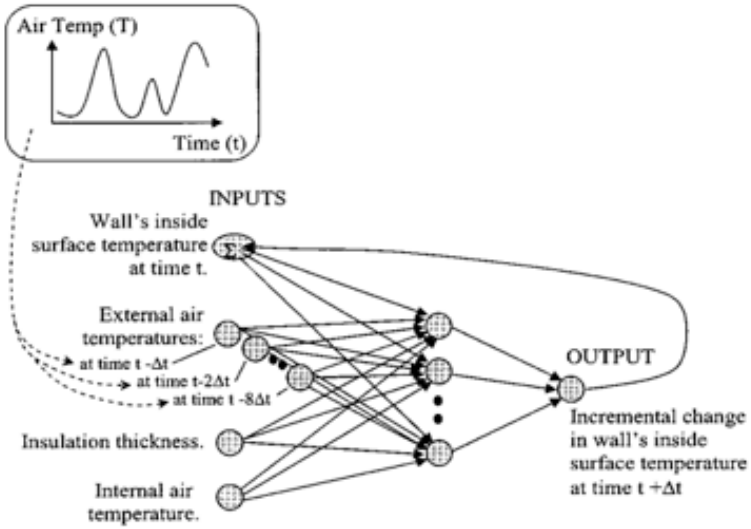

Figure 1: Corse-grain model for thermal behaviour of Buildings (Flood et al., 2008)

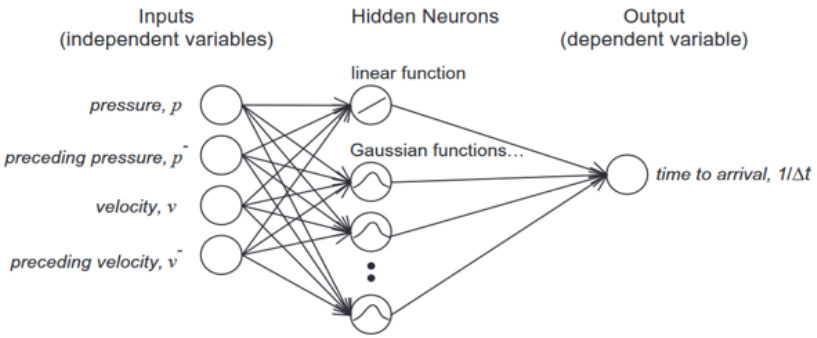

Figure 2: Corse-grain model for blast wave propagation (Flood et al., 2012)

Literature Review

- Latent space integrated interpolation for fluid

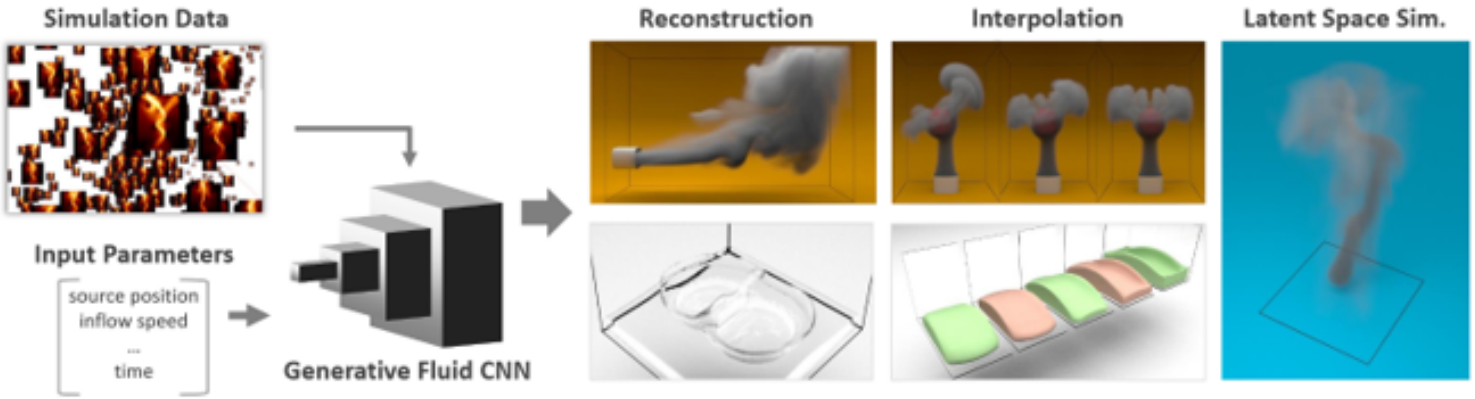

Figure 3: Latent space integrated interpolation for fluid (Kim et al., 2019)

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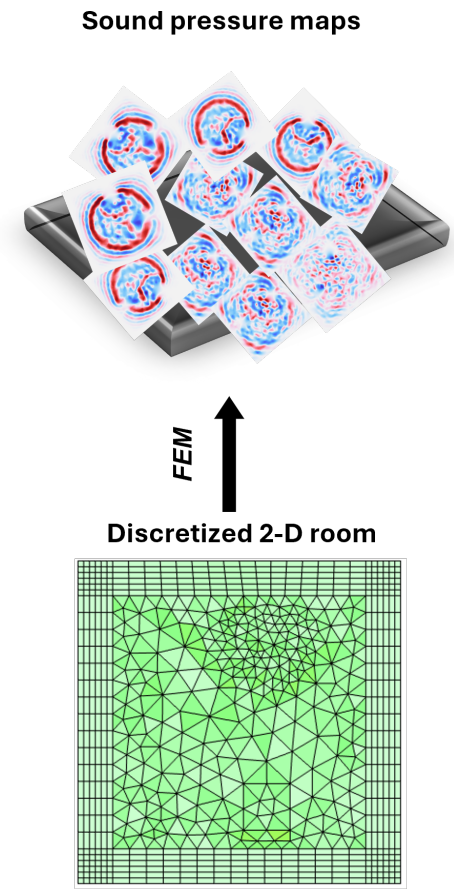
Methodology

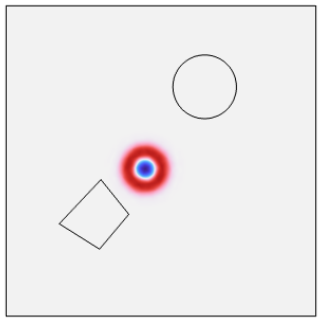
- Dataset generated by Comsol



FEM in Comsol		
FEM Parameters	Sound Source	Gaussian Pulse
	Frequency Domain	0 Hz - 250 Hz
	Boundary Conditions	PML
	Speed of Sound (c)	343 m/s
	Mesh Resolution	Fine Coarse Extra Fine Extra Coarse
	Time Step (Δt)	T0/20:0.2 ms T0/40 0.1 ms T0/60: 0.067 ms
Independent Variable	Location of sound source	(X,Y)
	Location of obstacle	(X,Y)
	Shape of obstacle	R
Dependent Variable	Sound pressure map (P)	Pa

Methodology

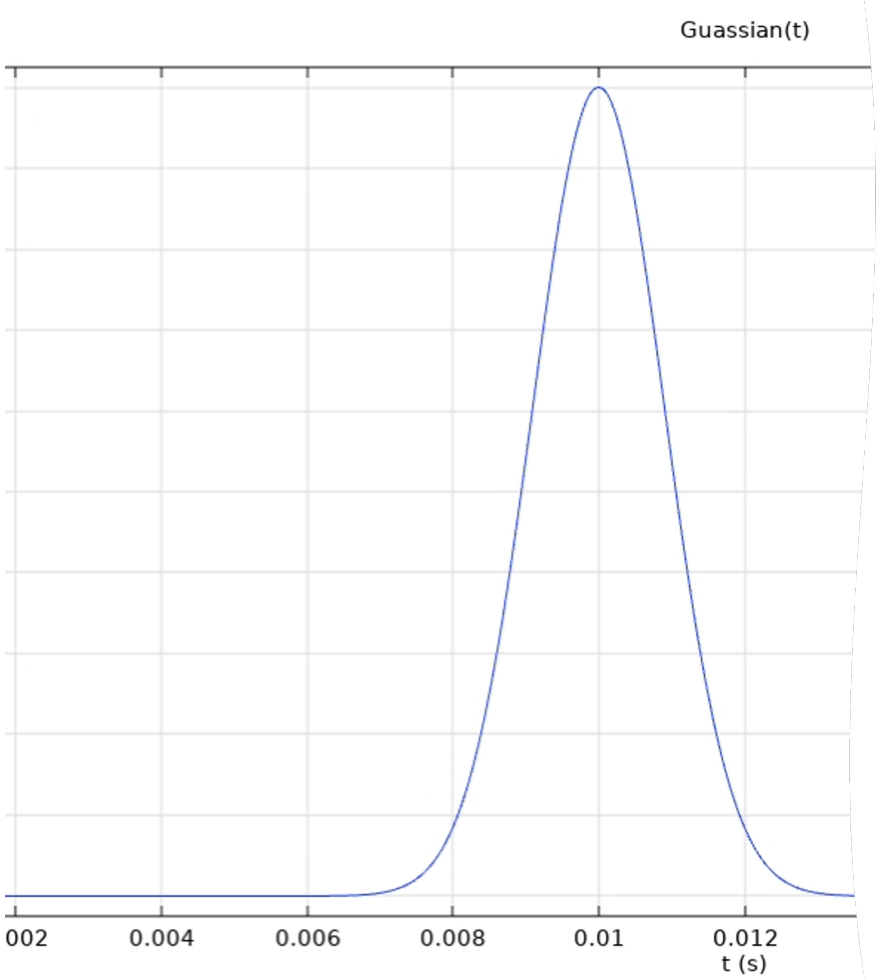
- Wave Equation



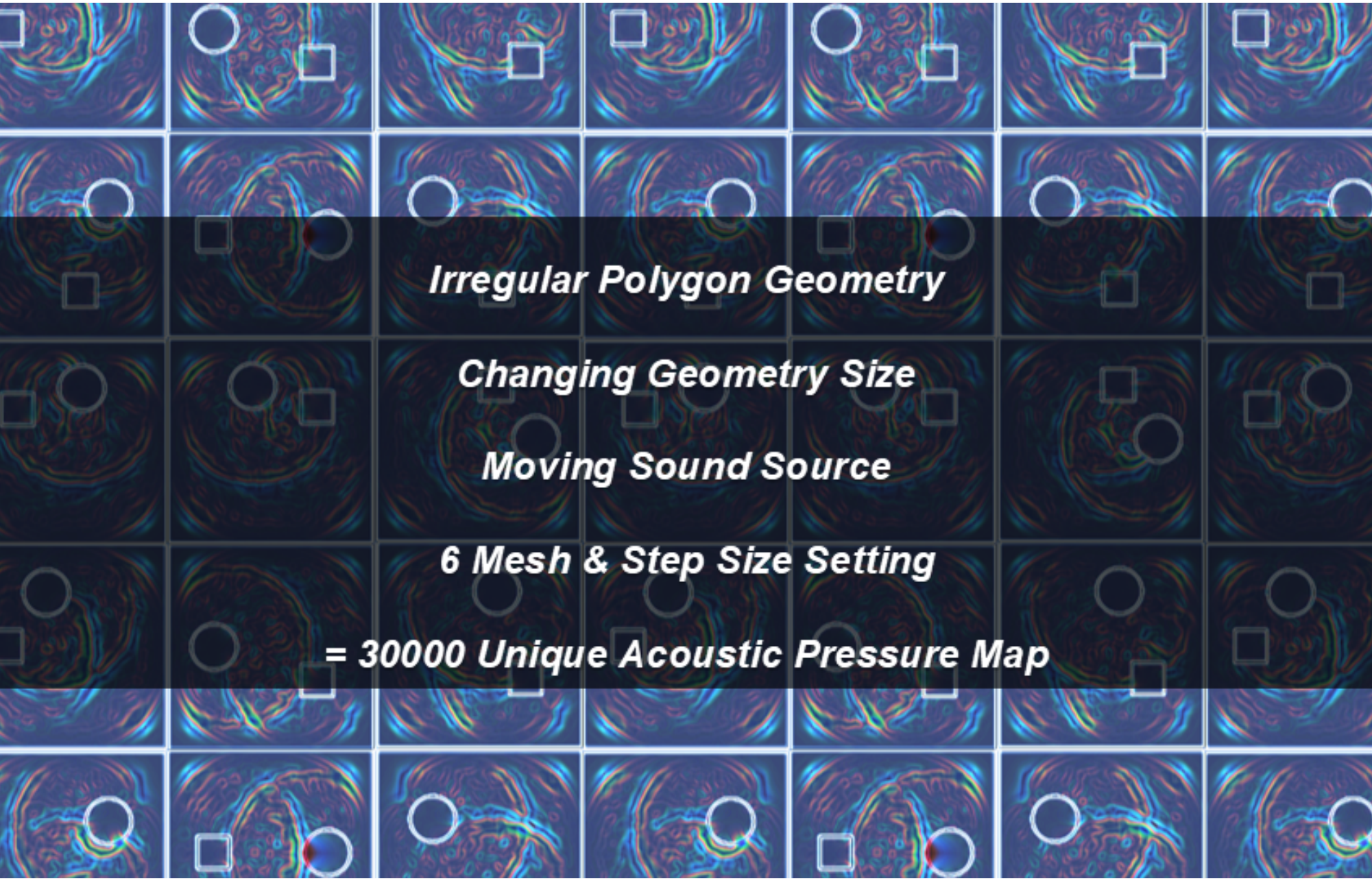
$$\frac{\partial^2 p(x,y,t)}{\partial t^2} = c^2 \left(\frac{\partial^2 p(x,y,t)}{\partial x^2} + \frac{\partial^2 p(x,y,t)}{\partial y^2} \right)$$

Methodology

- Sound Source

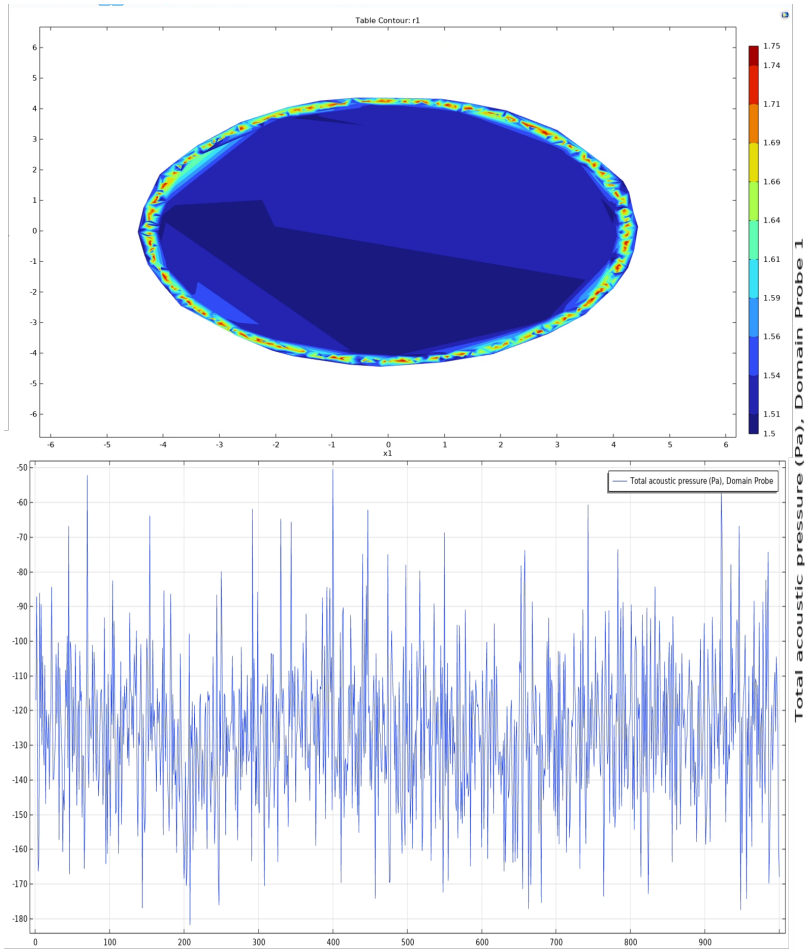


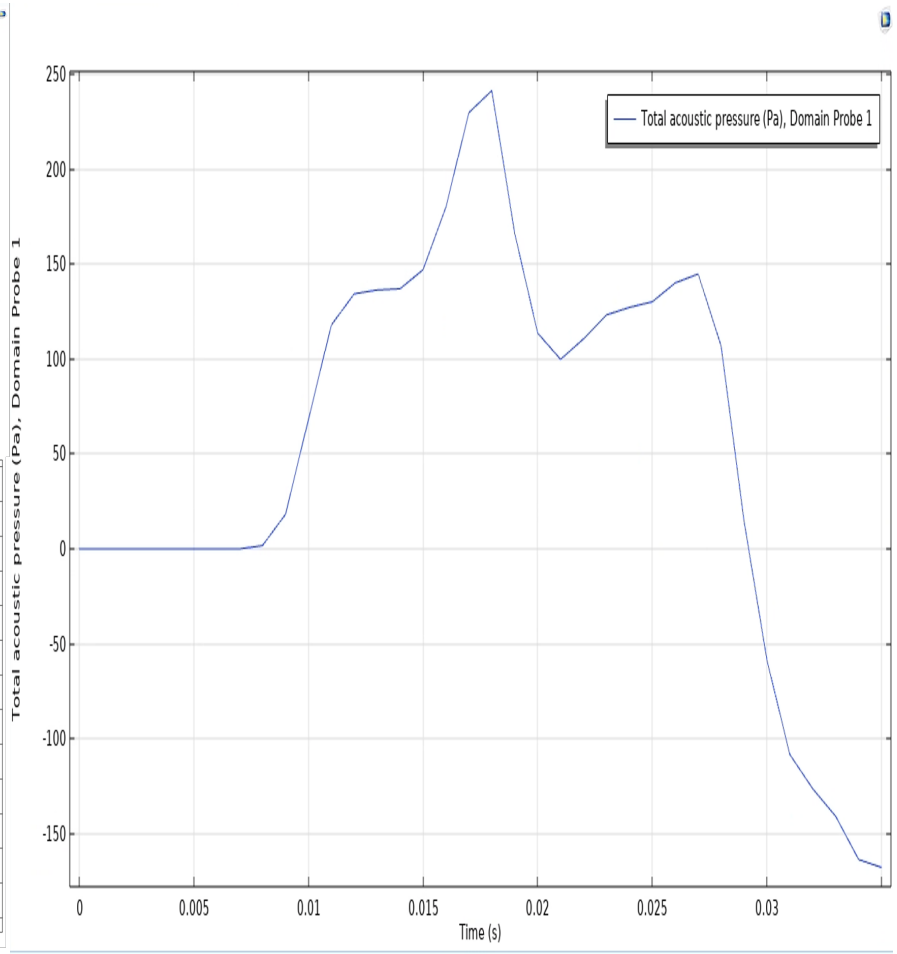
- $F(t) = Aexp\left(-\frac{(t-\mu)^2}{2\sigma^2}\right)$
- A is the amplitude
- μ is the mean (center of the pulse)
- σ controls the width (spread) of the pulse


Irregular Polygon Geometry
Changing Geometry Size
Moving Sound Source
6 Mesh & Step Size Setting
= 30000 Unique Acoustic Pressure Map

Methodology

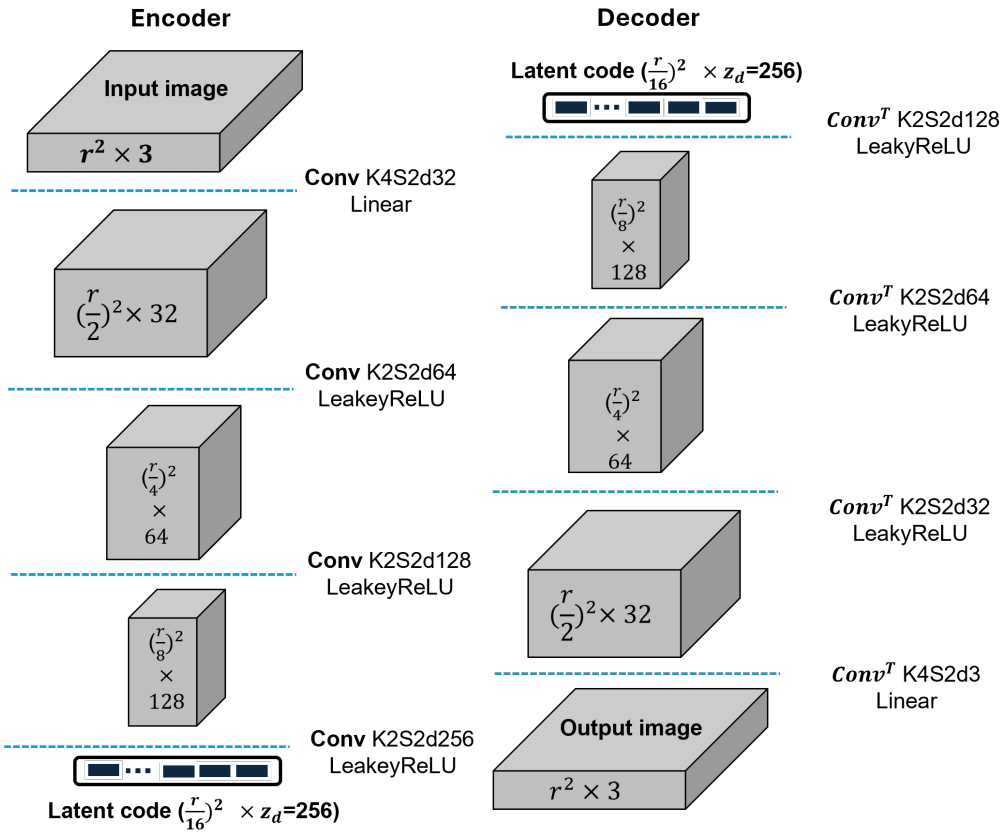
- Data Distribution

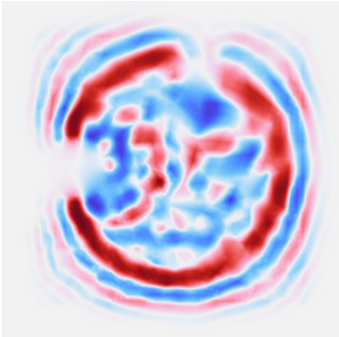


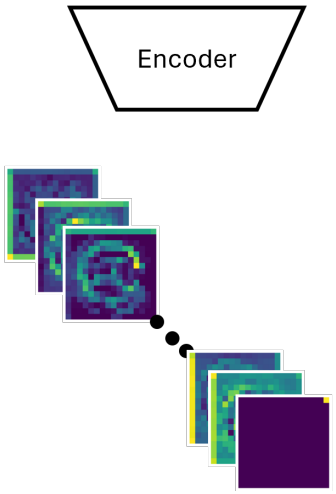


Methodology

- Reduced order

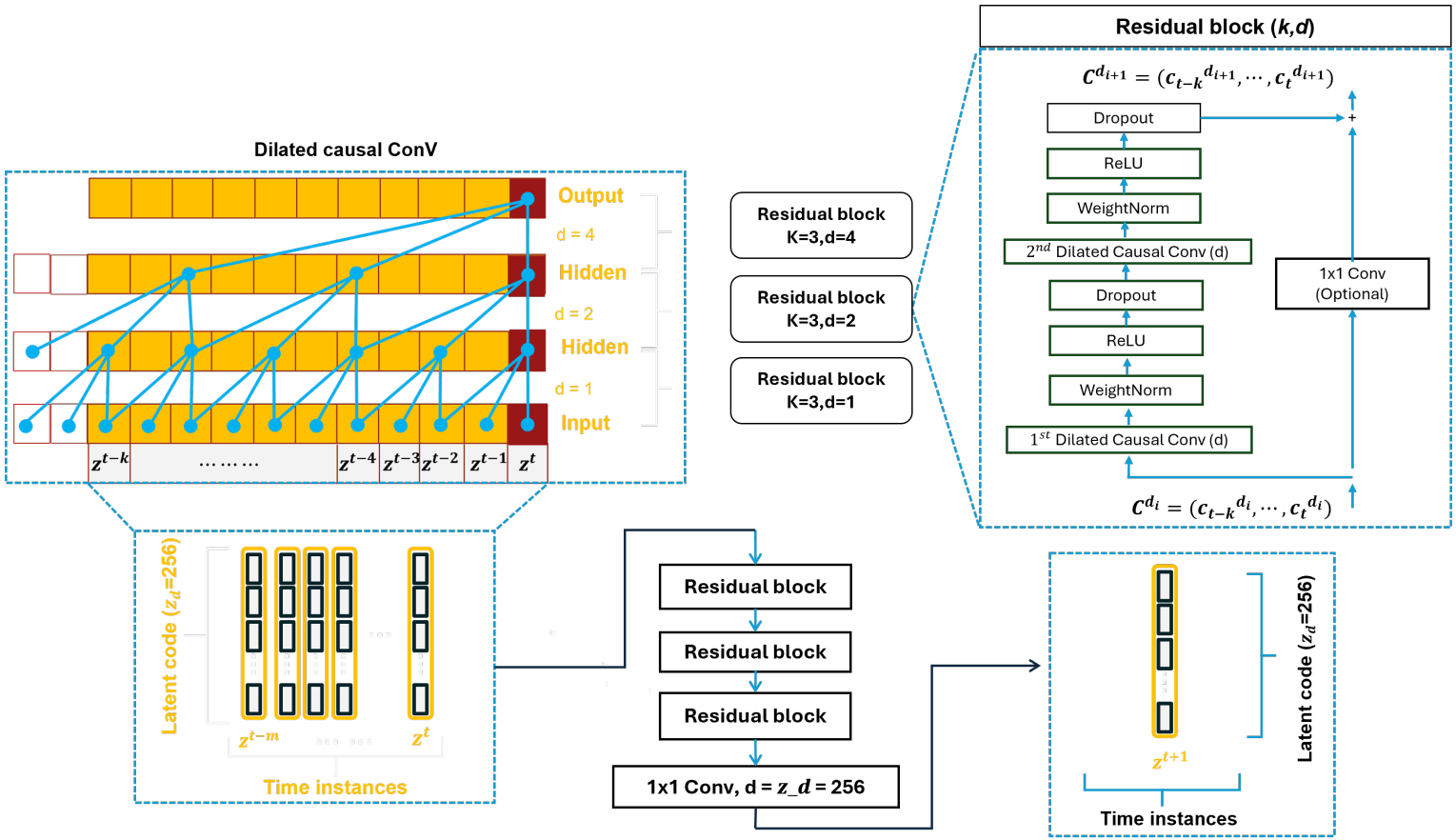






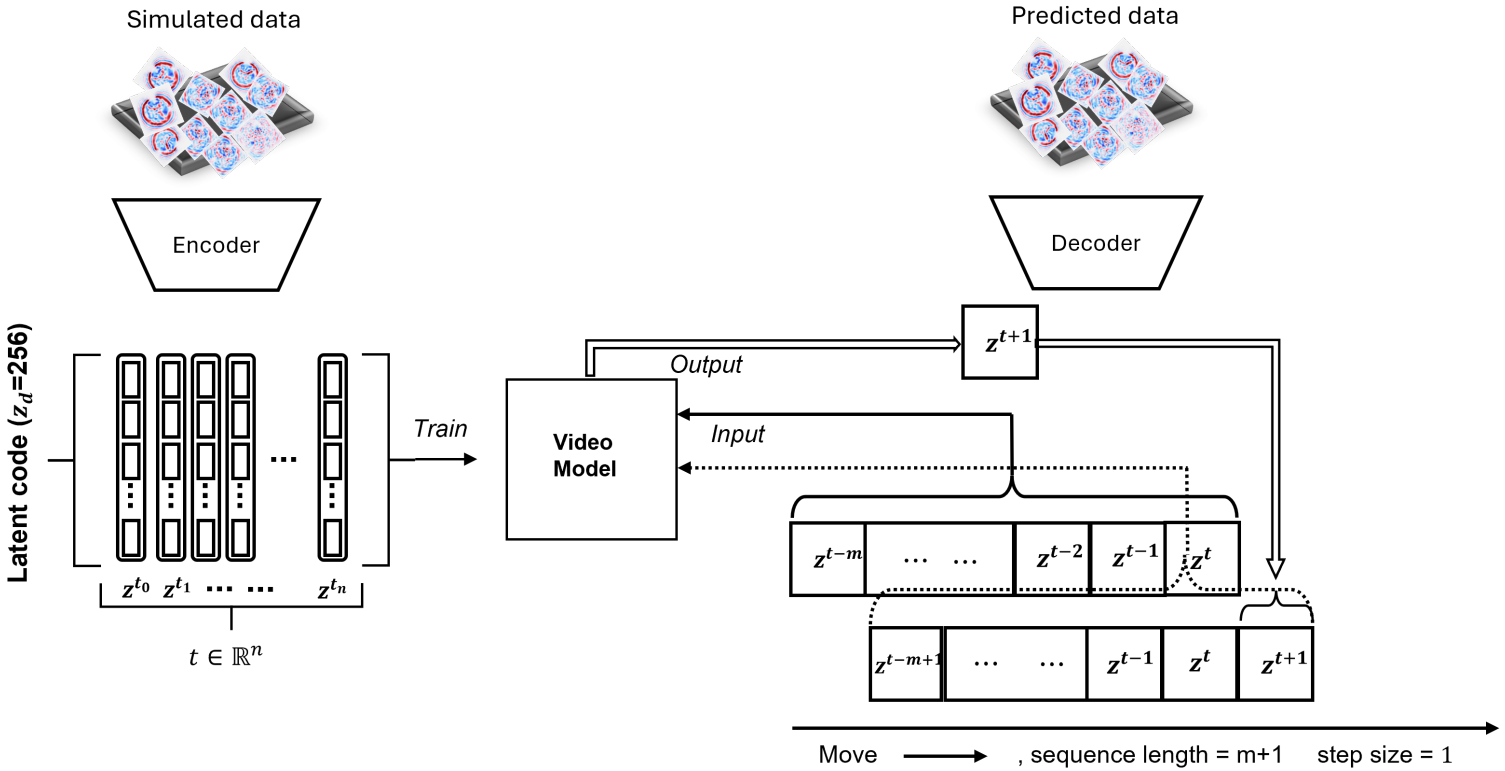
Methodology

- Model configuration



Methodology

- Flow of work



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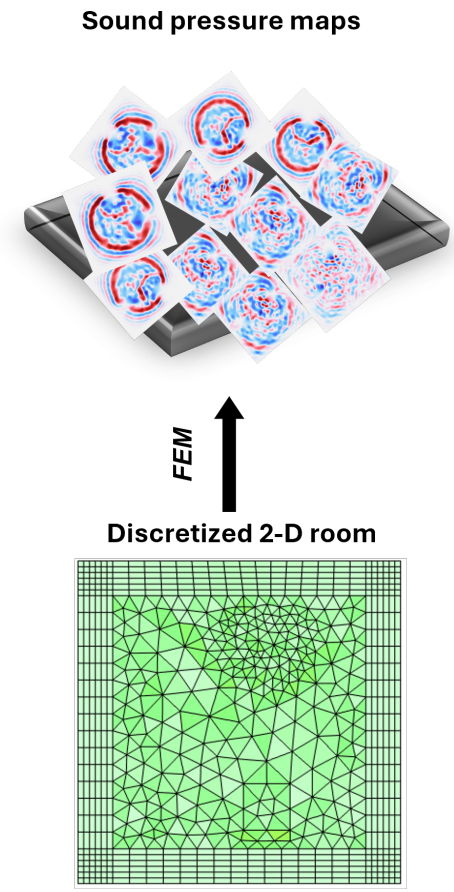
Experiment

- Data Configuration



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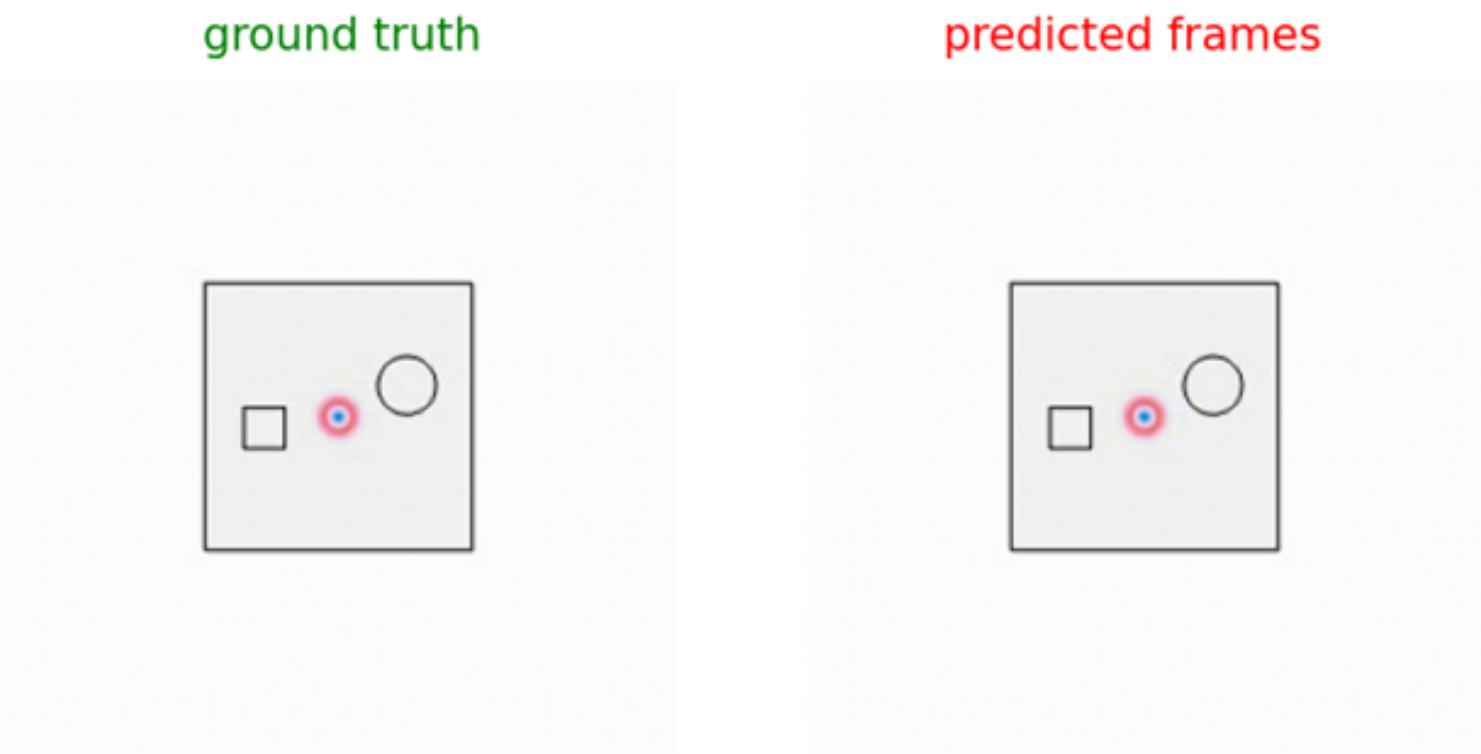
Dependent Variable	Sound pressure map (P)	Pa

Experiment

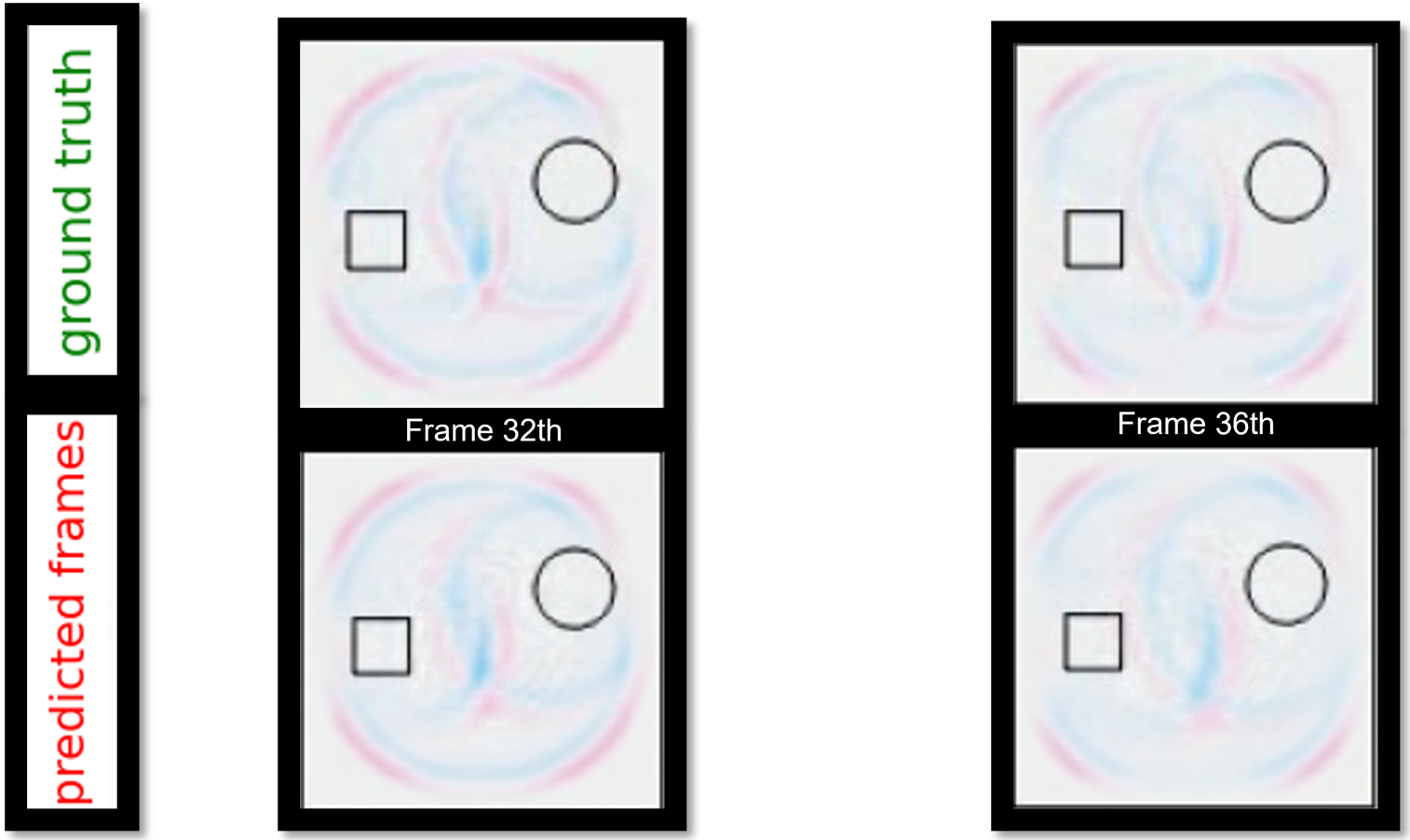
- Limited parameter experiment



Mesh	Time Step Size	Input	Independent Variable 1	Independent Variable 2
Fine	2 ms	5 frames	(x_c, y_c, r_c)	(x_s, y_s, r_s)

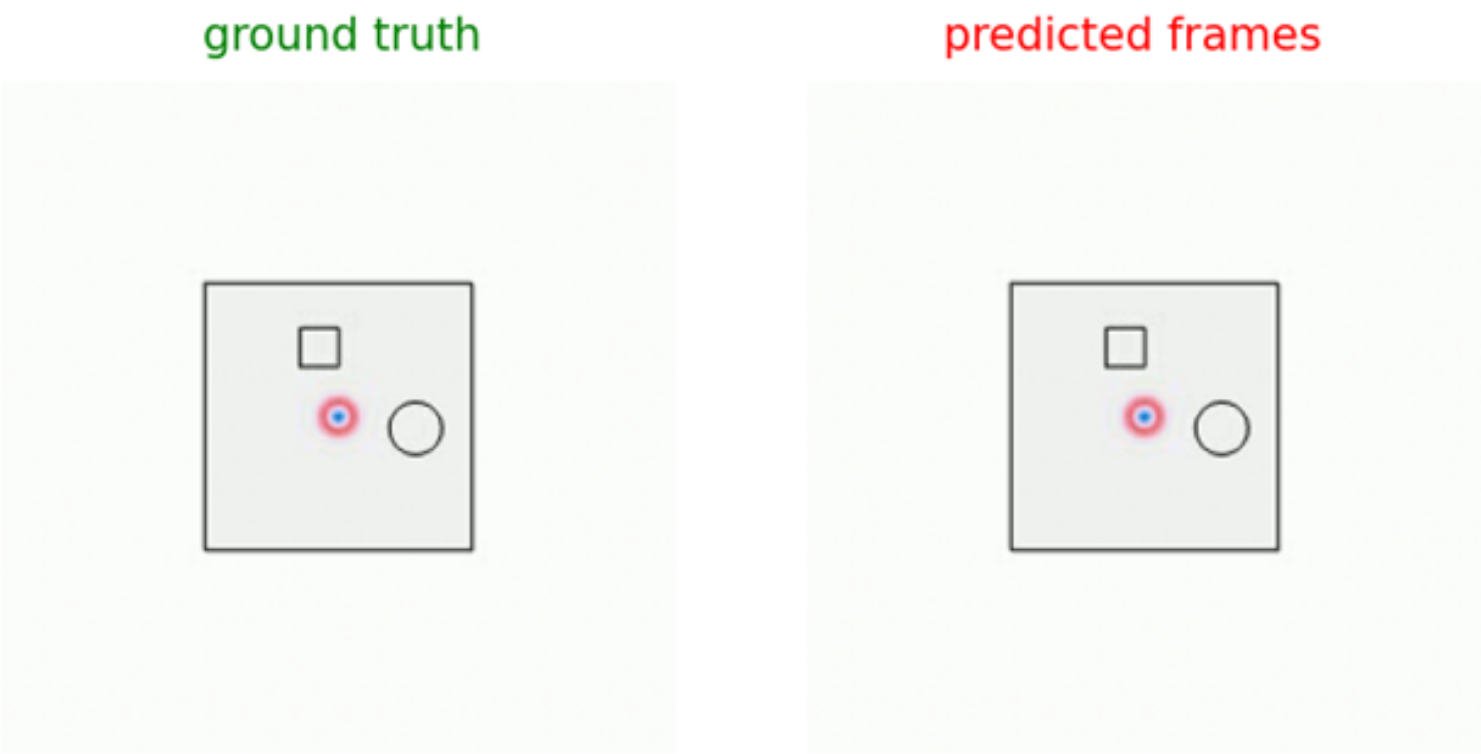
Experiment

- Close-up View for 5 Input



Experiment

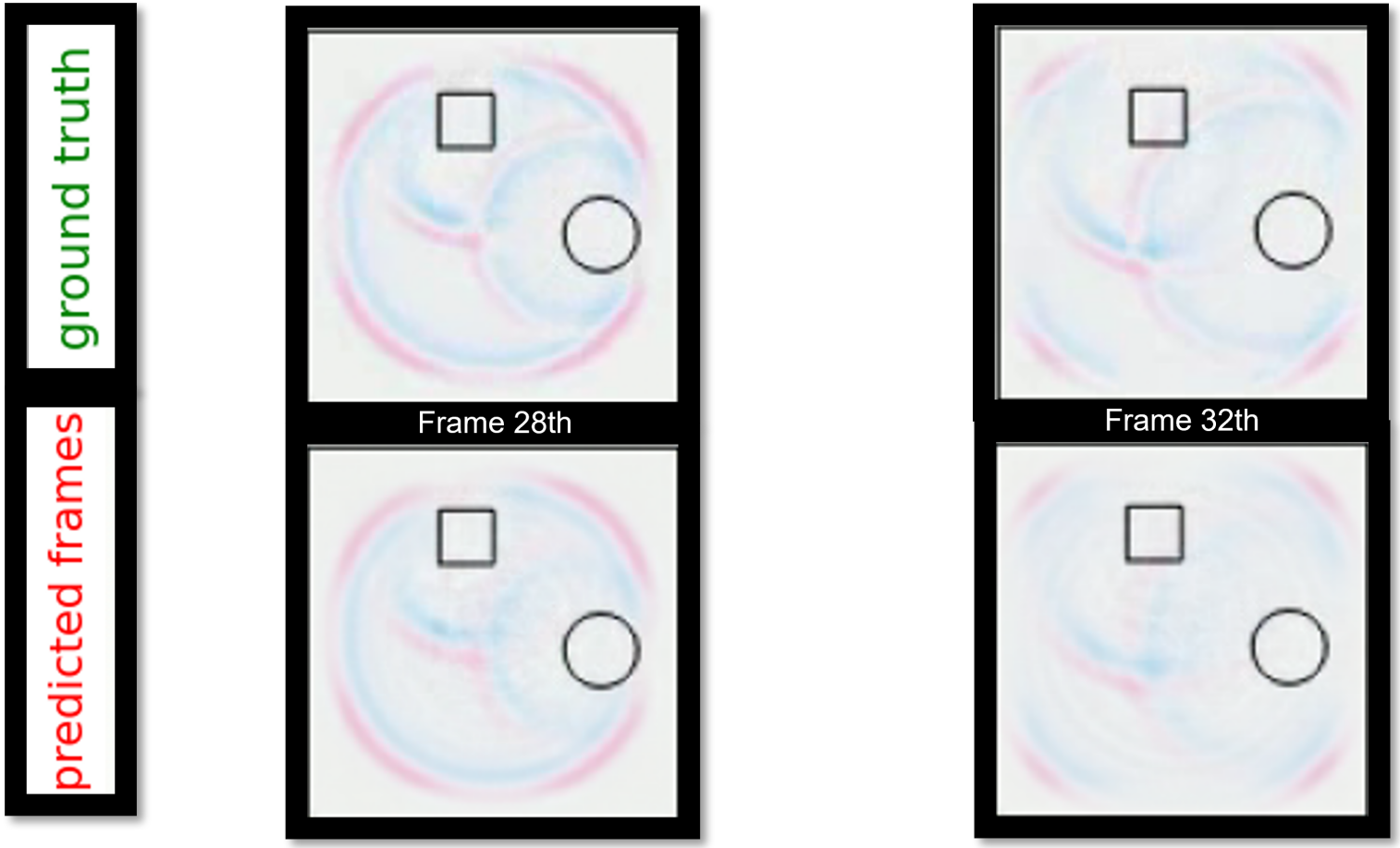
- Limited parameter experiment



Mesh	Time Step Size	Input	Independent Variable 1	Independent Variable 2
Fine	2 ms	3 frames	(x_c, y_c, r_c)	(x_s, y_s, r_s)

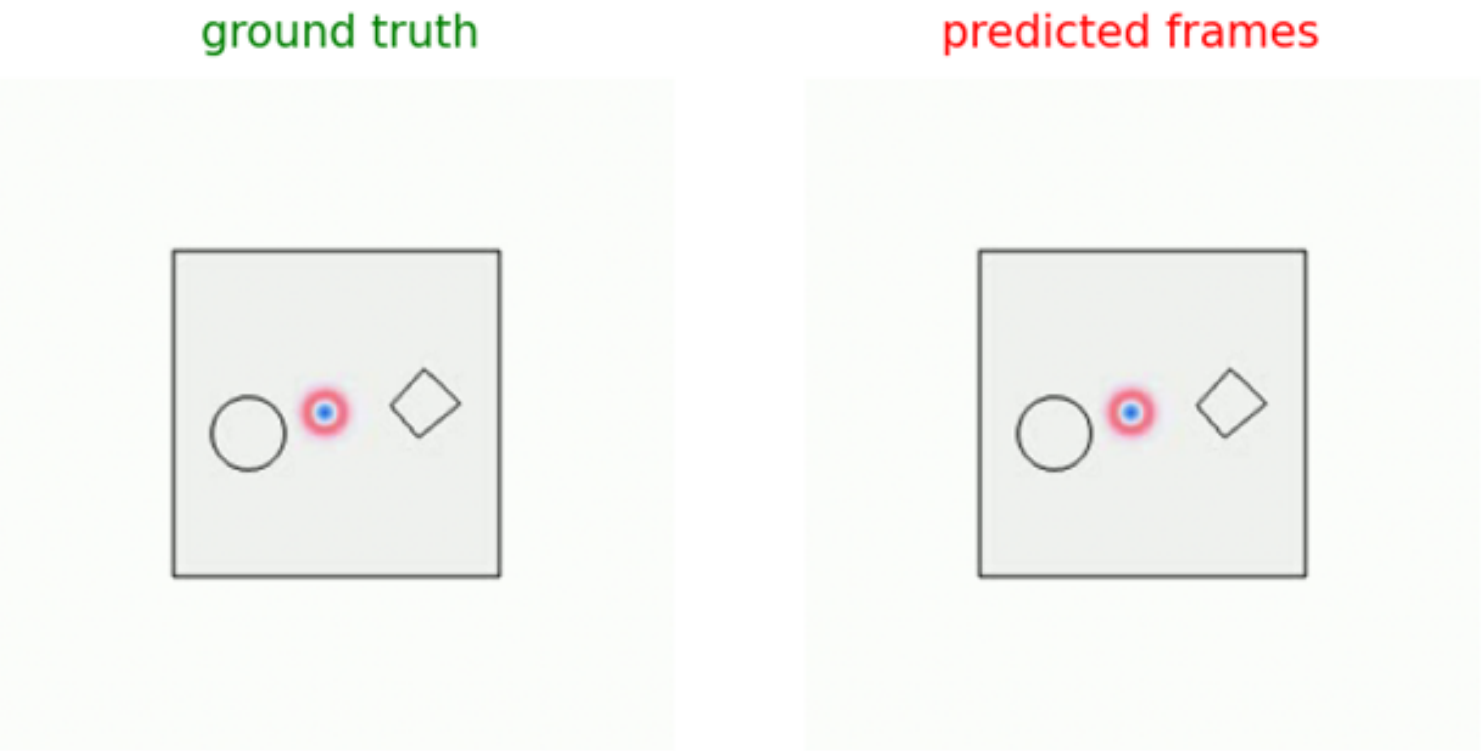
Experiment

- Close-up view for 3 Input



Experiment

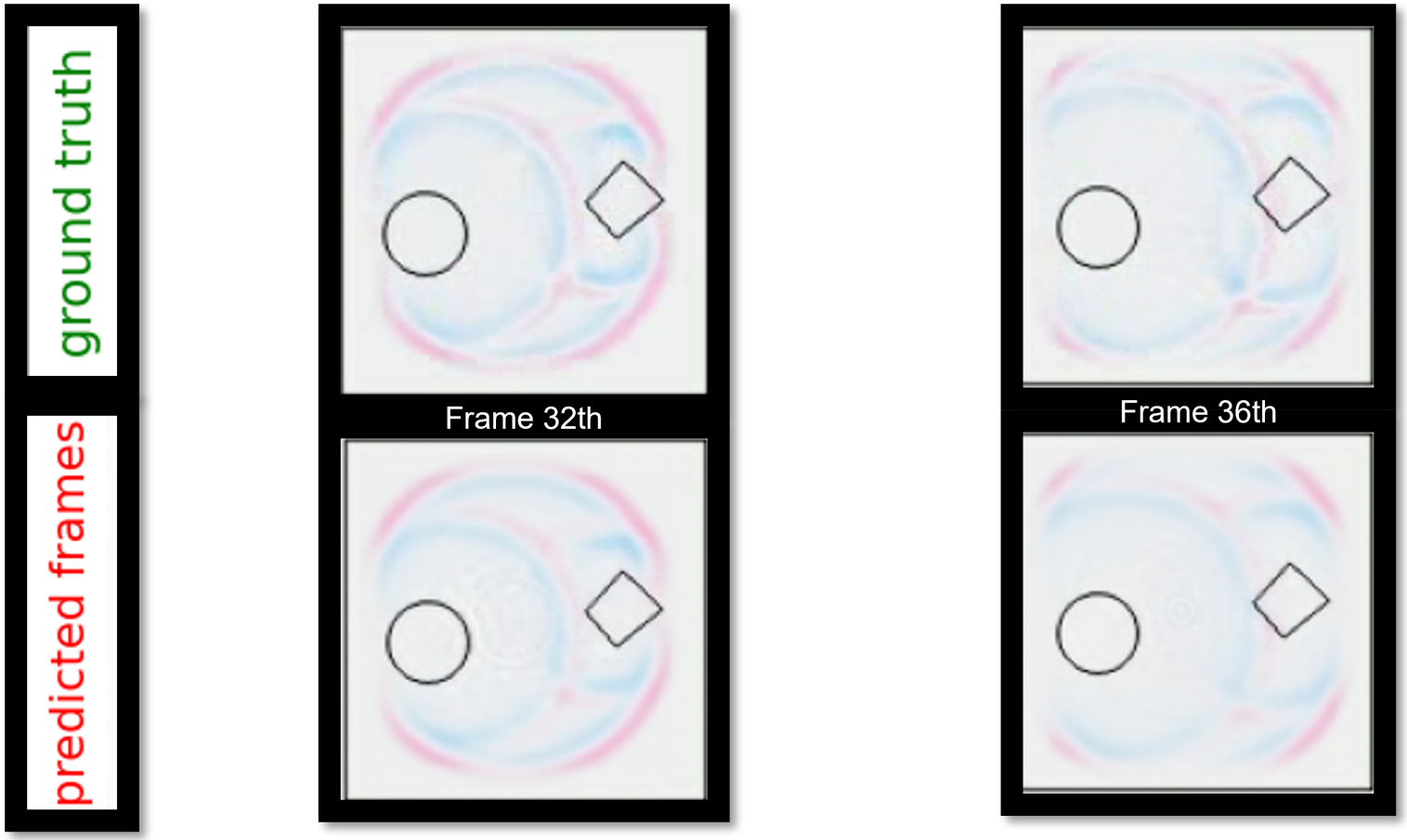
- Extended parameter experiment



Mesh	Time Step Size	Input	Independent Variable 1	Independent Variable 2	Independen 3
Finer	1 ms	5 frames	(x_c, y_c, r_c)	(x_p, y_p, r_p)	(x_s, y_s)

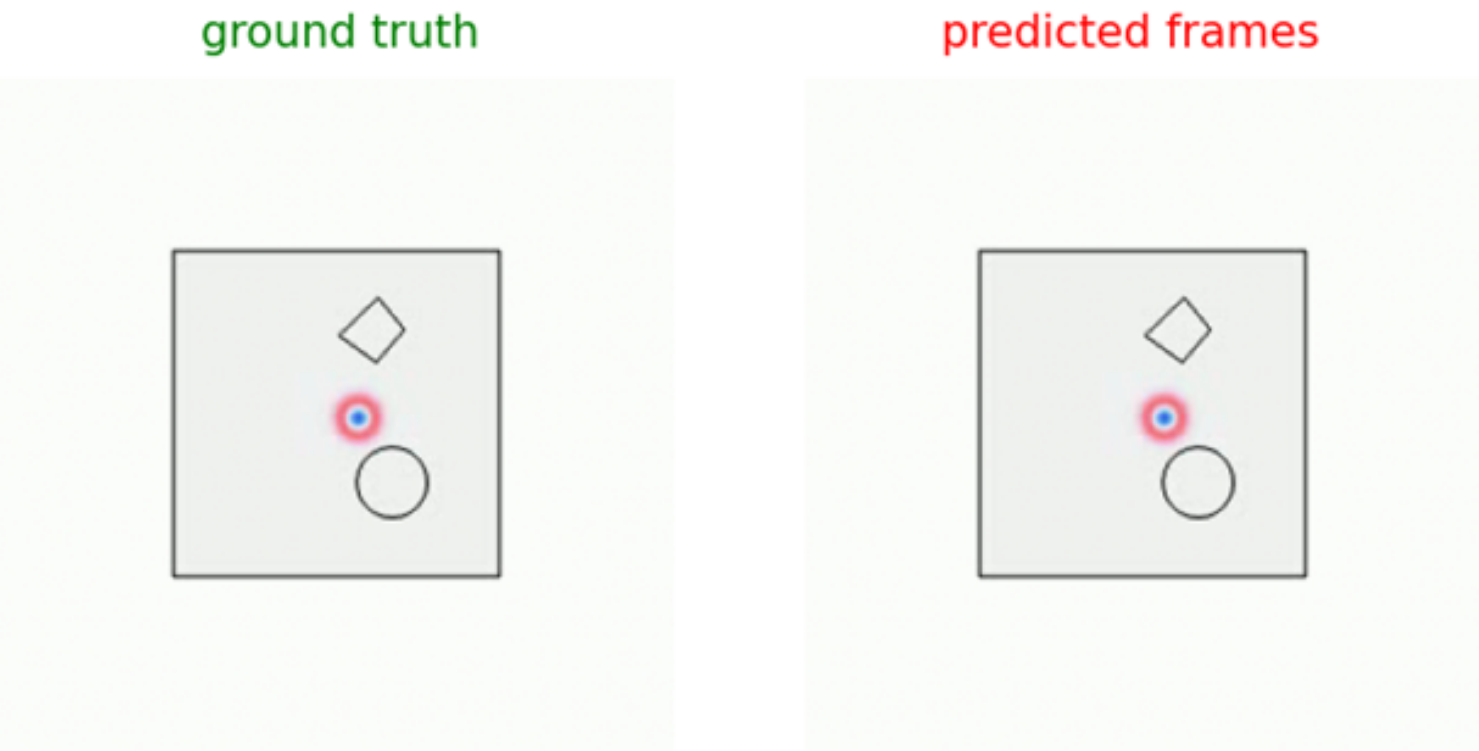
Conclusion

- Close-up View for 5 Input



Experiment

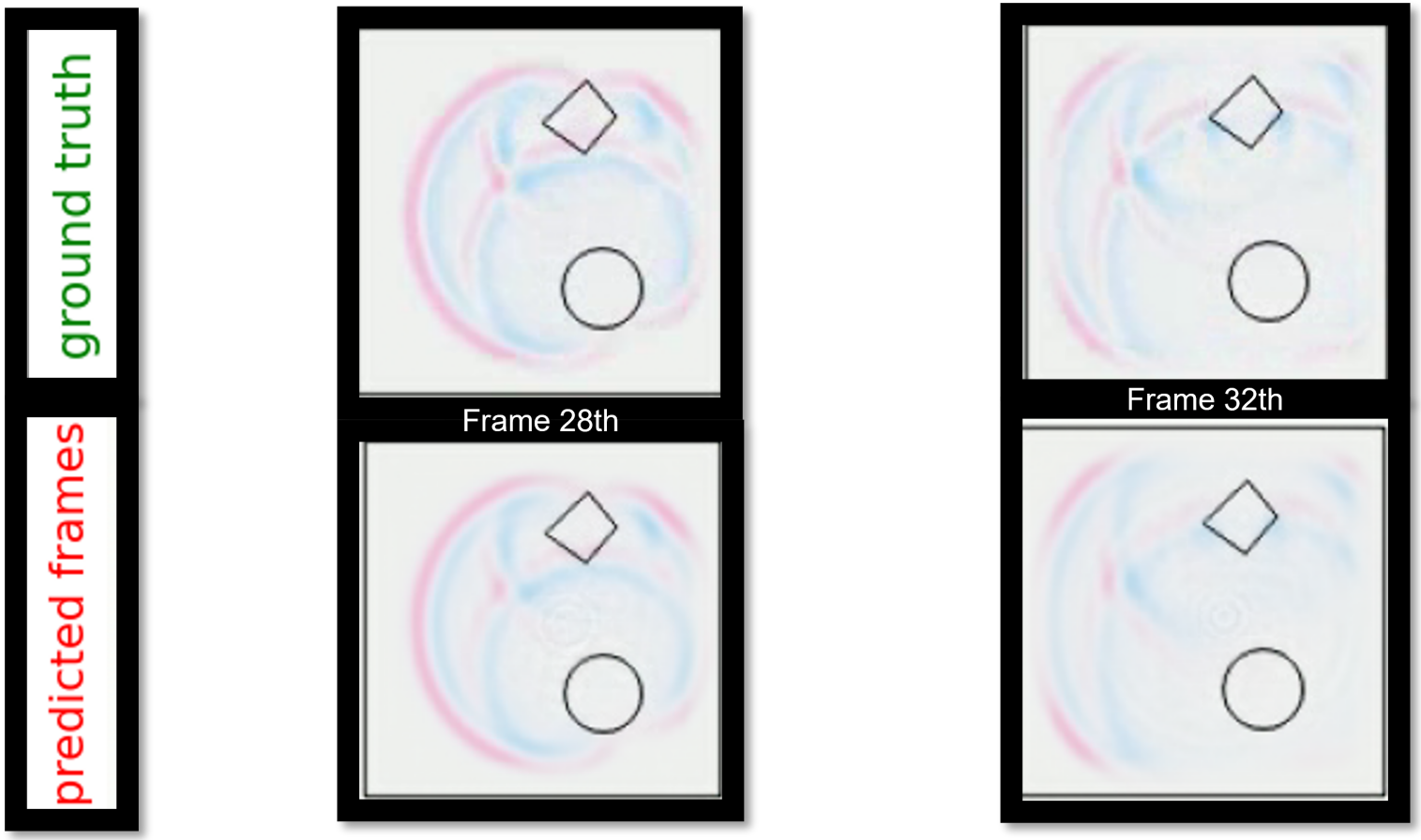
- extended parameter experiment



Mesh	Time Step Size	Input	Independent Variable 1	Independent Variable 2	Independen 3
Finer	1 ms	3 frames	(x_c, y_c, r_c)	(x_p, y_p, r_p)	(x_s, y_s)

Conclusion

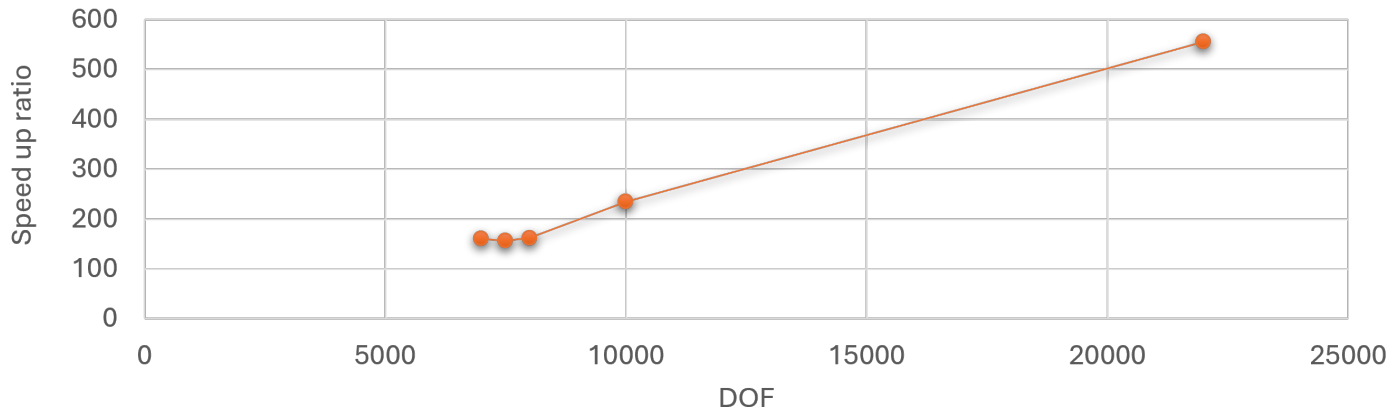
- Close-up view for 3 Input



Conclusion

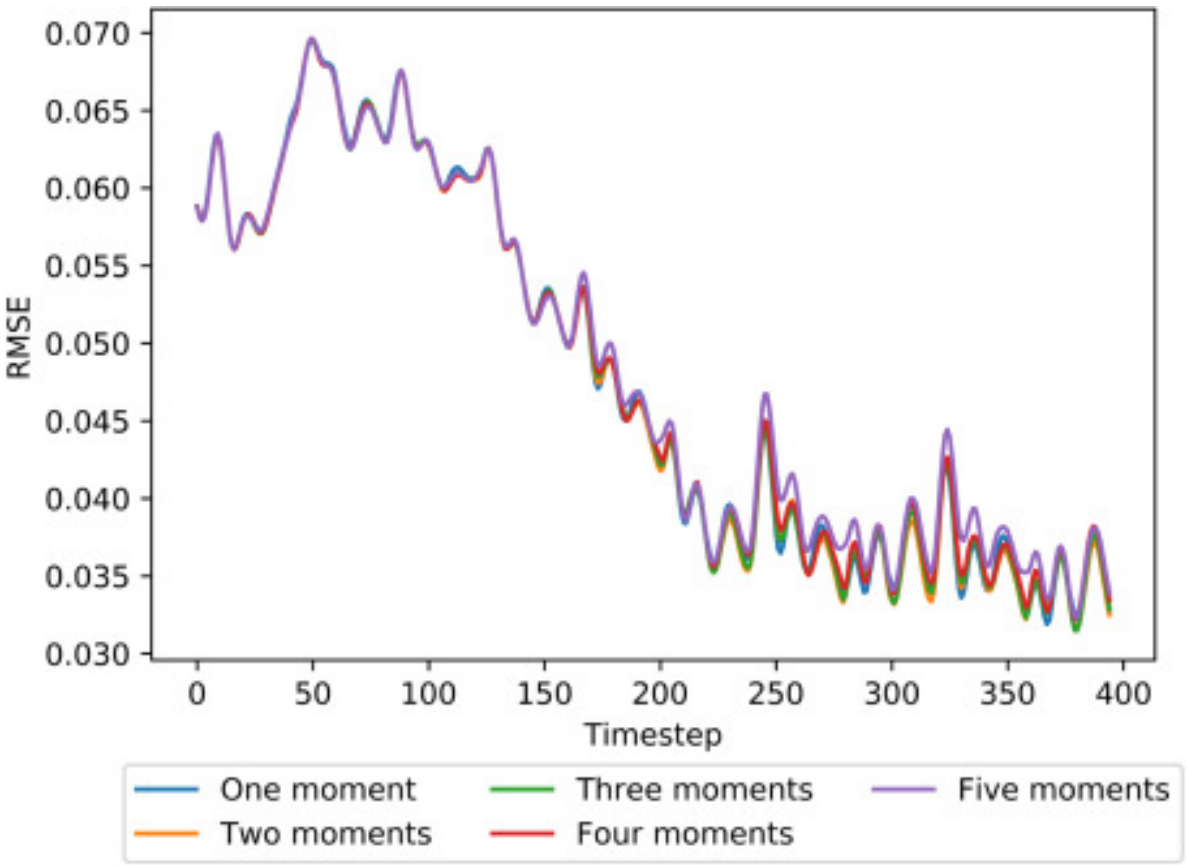
- Performance

Scene	Mesh Resolusion	DOF	*Step Size*	# Frame	Simulation Time (s)	Eval. Time (ms)	Spped Up (x)	Dataset Size	Training *Time (h)*
2D Time-Dependent Acoustic Pressure Map	*Fine*	*10000*	*0.0001*	*15000*	*5.02*	*2.12*	*130*	*252 mb*	*5h*
	Fine	*7500*	*0.001*	*15000*	*3.52*	*2.10*	*110*	*238 mb*	*5h*
	Fine	*8000*	*0.0005*	*30000*	*4.22*	*2.25*	*100*	*500 mb*	*8h*
	Finer	*22000*	*0.0005*	*15000*	*13*	*2.35*	*110*	*520 mb*	*5h*
	Coarser	*7000*	*0.0005*	*15000*	*3.3*	*2.12*	*80*	*185 mb*	*5h*



Conclusion

- Effect of the Quantity of Input on Prediction



Conclusion

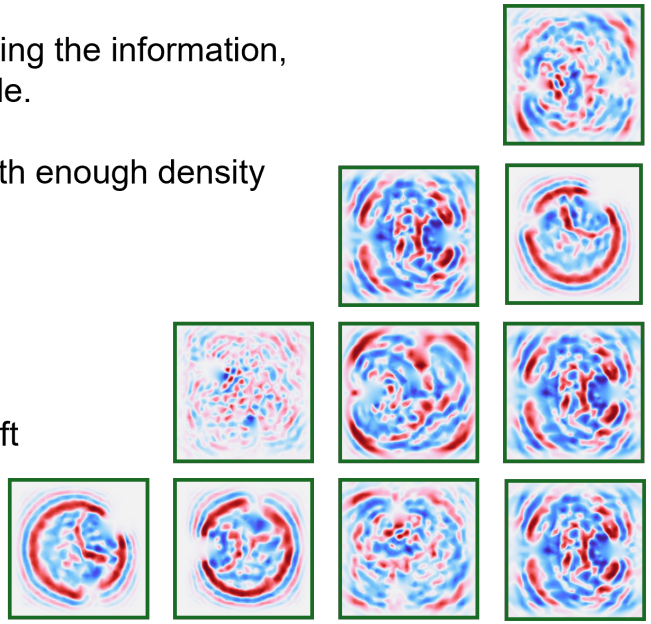
- Limitation

❖ **Quality of Reconstruction**

- ▶ Reconstructed data is not sensitive to sudden change
  - Generative model are good at capturing the information, but details are not physically plausible.
- ▶ Ghosting may happen if data is not sampled with enough density

❖ **Latent space integration**

- ▶ Latent space of AE can be improved
- ▶ Should add collaborative point to avoid data drift



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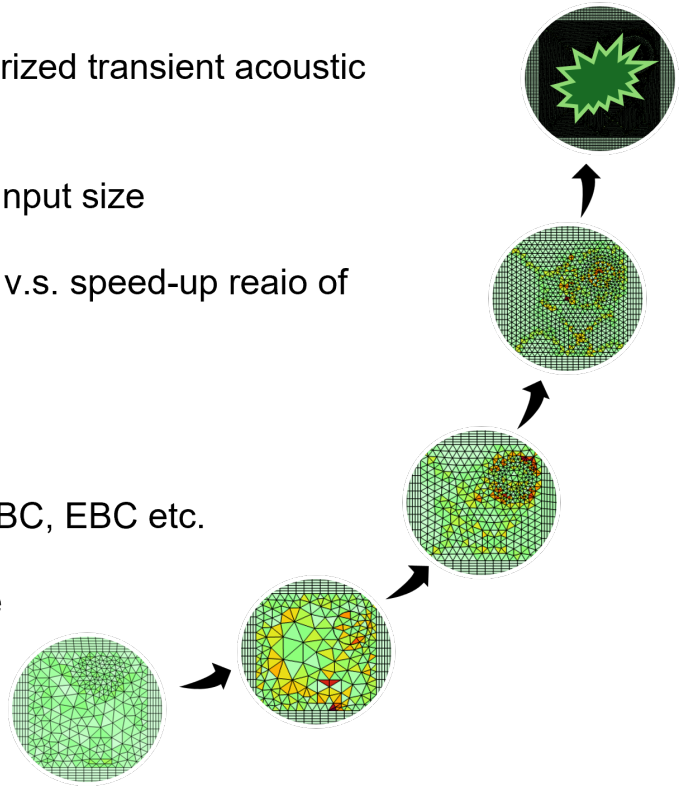
Contribution and future work

❖ Contributions

- First and plausible approximation of parameterized transient acoustic pressure simulation.
- Comparison among different among different input size
- Trade-off between spatial-temporal resolution v.s. speed-up reaio of generative model

❖ Future work

- Boundary conditions should be extended to ABC, EBC etc.
- scene should be applied to 3D model in future
- Frequency range should be covered more



Thanks for Coming

Any Questions?