GS-Hider: Hiding Messages into 3D Gaussian Splatting

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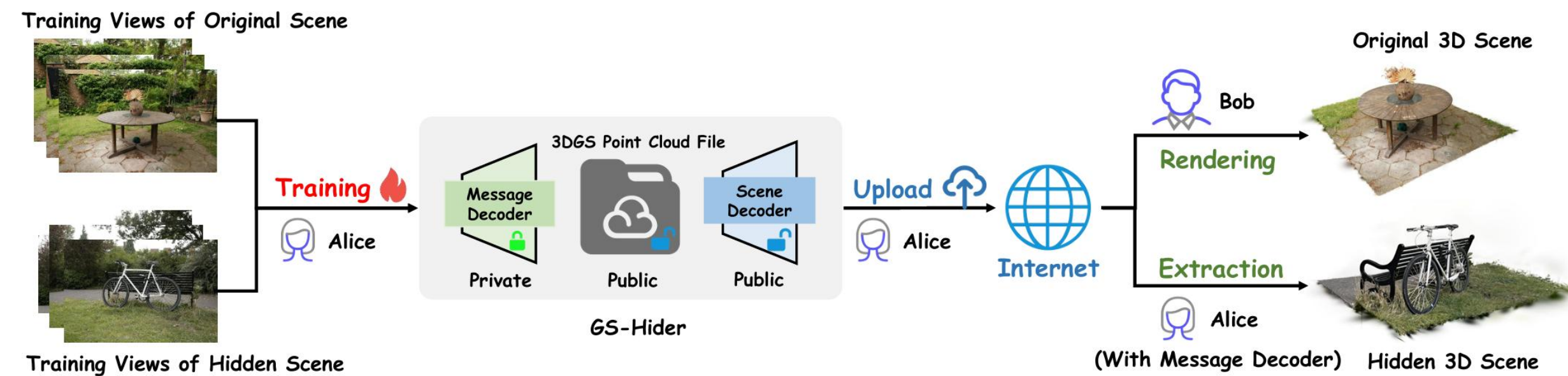
Application Scenario

Alice trains the GS-Hider using the 3DGS point cloud, scene, and message decoders. She uploads the point cloud and scene decoder online. Bob, as a 3DGS user, can render the original scene, but only Alice can extract the hidden scene, ensuring copyright protection or secret communication.

Task Setting

Encryption Communication: Hiding 3D scenes in an 3D scene. We use the original 3D scene to protect secret 3D scenes from malicious theft and extraction by stealers.

Copyright Protection: Hiding an image in a fixed view of the 3D scene. By comparing a pre-added image with the decoded one, the ownership of the 3DGS is verified.

Some Intuitive Approaches
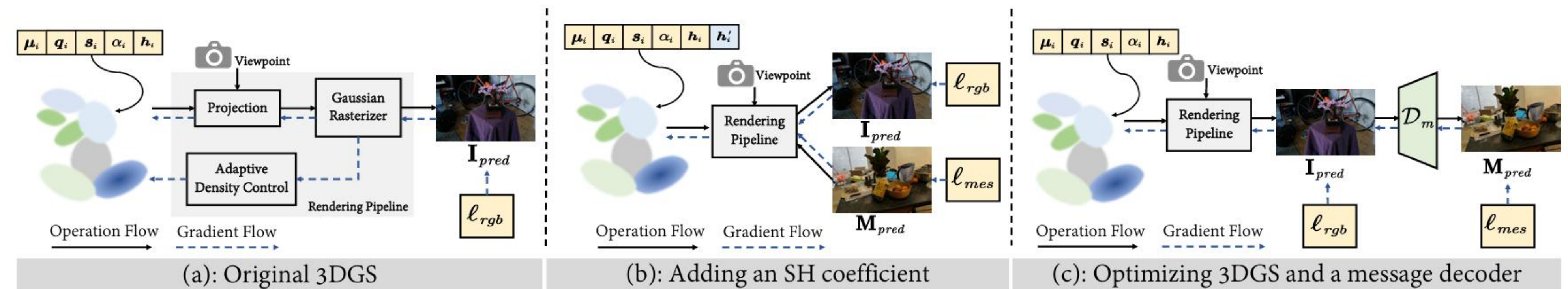

(a): Original 3DGS (b): Adding an SH coefficient (c): Optimizing 3DGS and a message decoder

Simply adding attributes or treating the 3DGS as a black box and jointly optimizing it with a decoder fails to meet the requirements for 3DGS steganography in security and fidelity

Overall Framework of our GS-Hider

$$\mathbf{F}_{coup}[\mathbf{p}] = \sum_{i=1}^{N} \boldsymbol{f}_i \sigma_i \prod_{j=1}^{i-1}(1-\sigma_j),$$

$$\mathbf{I}_{pred} = \mathcal{D}_s(\mathbf{F}_{coup})$$

$$\mathbf{M}_{pred} = \mathcal{D}_m(\mathbf{F}_{coup})$$
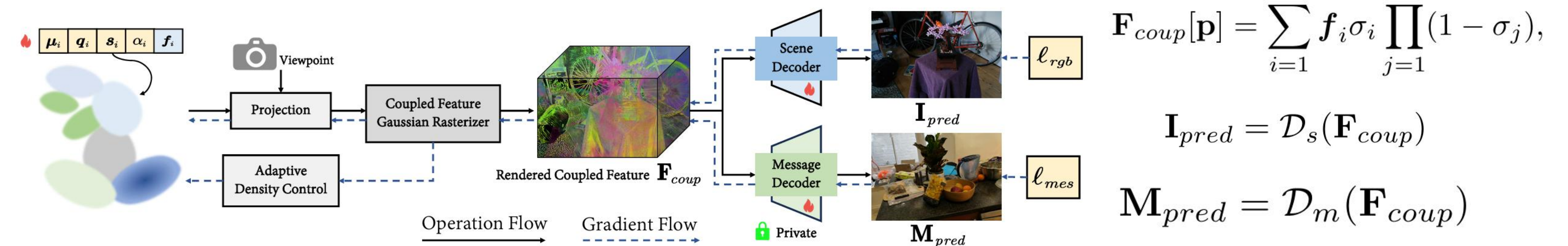
➤ Design a **coupled secured feature attribute** to replace the original 3DGS's spherical harmonics coefficients
➤ Use a scene decoder and a message decoder to **disentangle** the original RGB scene and the hidden message

Experimental Results

Hiding a 3D Scene in a 3D Scene

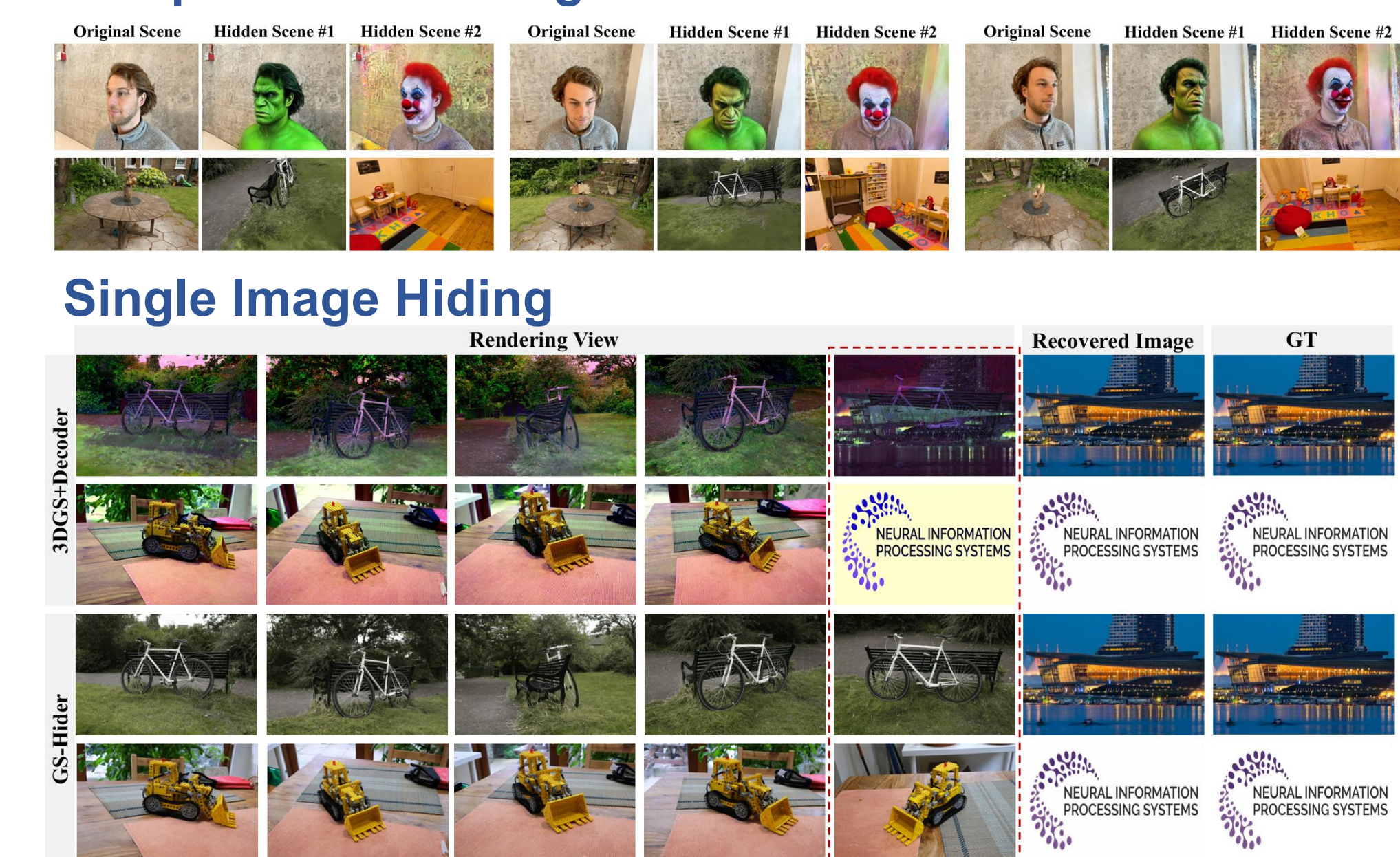| Method	Type	Size (MB)	Bicycle	Flowers	Garden	Stump	Treehill	Room	Counter	Kitchen	Bonsai	Average
3DGS	Scene	796.406	25.246	21.520	27.410	26.550	22.490	30.632	28.700	30.317	31.980	27.205
3DGS+SH	Scene	804.541	23.365	18.998	24.897	22.818	21.479	29.311	26.893	28.150	26.286	24.689
	Message		23.548	25.080	28.450	24.067	20.619	22.231	20.997	22.758	21.340	23.232
3DGS+Decoder	Scene	891.874	23.914	19.877	24.284	24.134	21.200	27.502	26.561	26.013	27.674	24.573
	Message		20.611	20.540	25.287	19.933	19.848	21.668	20.670	22.367	20.318	21.249
GS-Hider	Scene	411.356	24.018	20.109	26.753	24.573	21.503	28.865	27.445	29.447	29.643	25.817
	Message		28.219	26.389	32.348	25.161	20.276	22.885	20.792	26.690	23.846	25.179

Hiding a copyright image in a 3D Scene

Method	Type	Bicycle	Flowers	Garden	Stump	Treehill	Room	Counter	Kitchen	Bonsai	Average
3DGS	Scene	25.246	21.520	27.410	26.550	22.490	30.632	28.700	30.317	31.980	27.205
3DGS+Decoder	Scene	18.320	15.224	20.901	21.884	17.435	23.878	23.322	21.174	22.481	20.513
	Message	37.210	35.564	36.228	36.548	35.844	36.924	38.833	39.261	39.261	36.952
GS-Hider (Image)	Scene	24.140	20.660	26.971	25.569	22.077	30.274	28.267	29.844	30.115	26.440
	Message	39.900	43.363	39.923	39.828	39.795	39.857	42.290	47.300	50.530	42.532

Single Scene Hiding

Multiple Scene Hiding

Single Image Hiding