

Dynamic Scene Modeling and Rendering: A Survey of Methods and Applications

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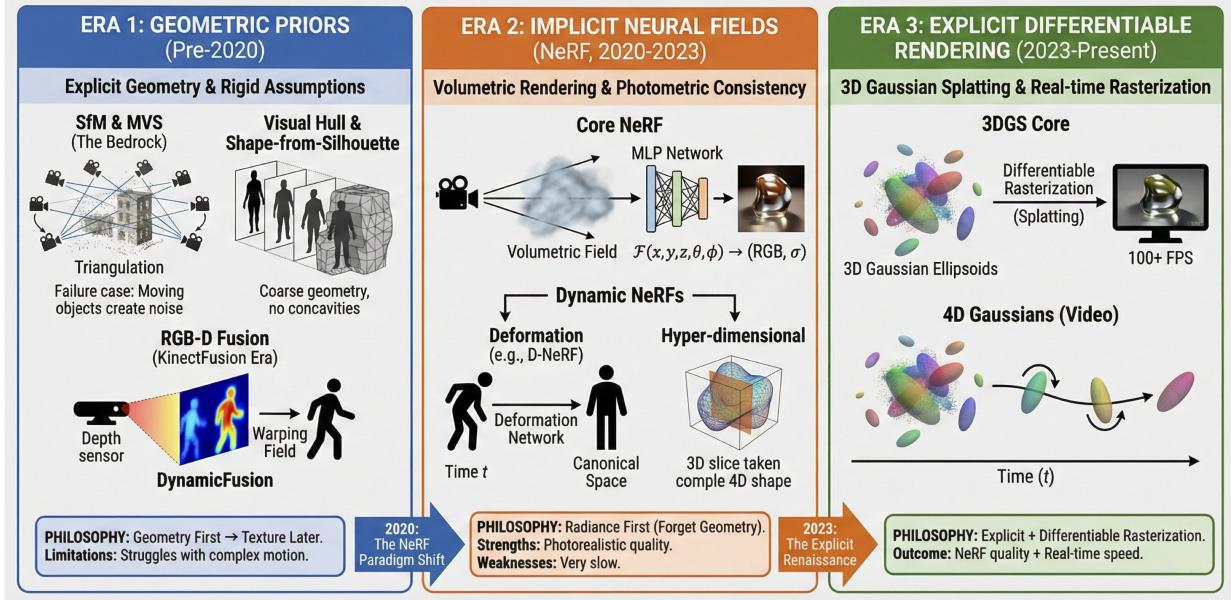


Fig. 1: Visualization of the evolution of video-based 3D reconstruction

Abstract—Dynamic scene modeling and reconstruction from video streams have witnessed a paradigm shift with the advent of Neural Radiance Fields (NeRF) and 3D Gaussian Splatting (3DGS). While NeRF-based methods offer photorealistic quality via implicit neural representations, they often suffer from prohibitive training and rendering costs. Recently, 3DGS has emerged as a powerful alternative, enabling real-time rendering through explicit splatting techniques, though it introduces new challenges regarding storage overhead and temporal consistency. In this paper, we present a comprehensive survey of video-based 3D reconstruction methods, categorizing them into implicit and explicit approaches. We systematically evaluate their trade-offs in terms of rendering quality, speed, and memory consumption across diverse scenarios. Furthermore, we summarize the limitations of current state-of-the-art methods and discuss future directions. Our compiled resources and code are available at <https://github.com/8barbatos/Academic-English-Group-Paper>.

Index Terms—3D Reconstruction, Dynamic Scene Modeling, Neural Radiance Fields (NeRF), Gaussian Splatting, Novel View Synthesis, Survey.

I. Introduction

With the rapid advancement of virtual reality (VR), augmented reality (AR), and the Metaverse, the demand for

photorealistic 3D content creation has surged exponentially. Dynamic scene modeling, which aims to reconstruct 3D geometry and appearance from 2D video streams, serves as a fundamental technology for these applications, enabling immersive telepresence, free-viewpoint video, and digital human avatars [1]. Unlike static scene reconstruction, modeling dynamic scenes from video presents a highly ill-posed inverse problem due to the entanglement of object motion, topology changes, and time-variant lighting conditions.

Traditionally, 3D reconstruction relied on Structure-from-Motion (SfM) and Multi-View Stereo (MVS) algorithms [2]. While these methods, such as COLMAP, provide robust camera pose estimation, they struggle to capture thin structures and view-dependent effects (e.g., reflections). More importantly, traditional pipelines typically assume a static world, making them brittle when applied to dynamic video sequences where geometry consistency is violated over time.

The field witnessed a paradigm shift with the introduction of **Neural Radiance Fields (NeRF)** [3]. By representing scenes as implicit continuous functions parameterized by Multi-Layer Perceptrons (MLPs), NeRF achieved unprecedented rendering

quality. Subsequent works, such as D-NeRF [4] and Nerfies [5], extended this implicit paradigm to dynamic domains by introducing deformation fields to handle non-rigid motion. However, implicit methods suffer from prohibitive computational costs due to the extensive ray-marching sampling required during both training and inference, limiting their deployment in real-time applications.

Recently, **3D Gaussian Splatting (3DGS)** [6] has emerged as a compelling alternative, marking a return to explicit volumetric representations. By combining the differentiability of deep learning with the efficiency of rasterization-based rendering, 3DGS enables real-time rendering (100+ FPS) and fast training speeds. This breakthrough has triggered a new wave of research focused on extending Gaussian primitives to 4D spatiotemporal modeling [7], [8], aiming to combine the efficiency of explicit representations with the flexibility of neural fields.

Despite the explosion of research papers in this domain, a systematic comparison between implicit (NeRF-based) and explicit (Gaussian-based) approaches for video modeling is lacking. In this survey, we provide a comprehensive review of the state-of-the-art methods for video-based 3D reconstruction. The main contributions of this paper are summarized as follows:

- We propose a structured taxonomy of dynamic scene modeling methods, categorizing them into *Deformation-based*, *Spacetime-based*, and *Hybrid* approaches across both implicit and explicit representations.
- We provide an in-depth analysis of the transition from NeRF to 3D Gaussian Splatting, highlighting the trade-offs between rendering quality, training efficiency, and storage overhead.
- We conduct a comparative evaluation of representative frameworks and discuss open challenges, including storage optimization and long-duration video modeling, to guide future research directions.

II. Prepare Your Paper Before Styling

Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sections II-A to II-H below for more information on proofreading, spelling and grammar.

Keep your text and graphic files separate until after the text has been formatted and styled. Do not number text heads—*L^AT_EX* will do that for you.

A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

B. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
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- Use a zero before decimal points: “0.25”, not “.25”. Use “cm³”, not “cc”).

C. Equations

Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \quad (1)$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(1)”, not “Eq. (1)” or “equation (1)”, except at the beginning of a sentence: “Equation (1) is . . .”

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Please use “soft” (e.g., \eqref{Eq}) cross references instead of “hard” references (e.g., (1)). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

Please don’t use the {eqnarray} equation environment. Use {align} or {IEEEeqnarray} instead. The {eqnarray} environment leaves unsightly spaces around relation symbols.

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Do not use `\nonumber` inside the `{array}` environment. It will not stop equation numbers inside `{array}` (there won't be any anyway) and it might stop a wanted equation number in the surrounding equation.

E. Some Common Mistakes

- The word “data” is plural, not singular.
- The subscript for the permeability of vacuum μ_0 , and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
- A graph within a graph is an “inset”, not an “insert”. The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).
- Do not use the word “essentially” to mean “approximately” or “effectively”.
- In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.
- Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
- Do not confuse “imply” and “infer”.
- The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the “et” in the Latin abbreviation “et al.”.
- The abbreviation “i.e.” means “that is”, and the abbreviation “e.g.” means “for example”.

An excellent style manual for science writers is [?].

F. Authors and Affiliations

The class file is designed for, but not limited to, six authors. A minimum of one author is required for all conference articles. Author names should be listed starting from left to right and then moving down to the next line. This is the author sequence that will be used in future citations and by indexing services. Names should not be listed in columns nor group by affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization).

G. Identify the Headings

Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is “Heading 5”. Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract”, will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced.

H. Figures and Tables

a) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation “Fig. ??”, even at the beginning of a sentence.

TABLE I: Table Type Styles

Table Head	Table Column Head		
	Table column subhead	Subhead	Subhead
copy	More table copy ^a		

^aSample of a Table footnote.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity “Magnetization”, or “Magnetization, M”, not just “M”. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write “Magnetization (A/m)” or “Magnetization {A[m(1)]}”, not just “A/m”. Do not label axes with a ratio of quantities and units. For example, write “Temperature (K)”, not “Temperature/K”.

Acknowledgment

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

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