Research Article

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3D CT Cinematic Rendering: Transforming Forensic Imaging with Enhanced Visualization for Skeletal Trauma Analysis

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ABSTRACT

Cinematic rendering (CR) is an innovative imaging technique that has emerged as a powerful tool in forensic radiology, offering enhanced visualization capabilities for the analysis of skeletal trauma. This article explores the application of CR in the setting of forensic imaging in skeletal injury and its impact on the field of skeletal trauma analysis. The study discusses the advantages of CR over traditional imaging methods and presents a comprehensive overview of the techniques, materials, and results associated with its application. The results indicate that CR has the potential to revolutionize forensic imaging, providing forensic experts with a highly accurate and detailed depiction of skeletal trauma for improved forensic analysis.

Keywords
Cinematic rendering, Forensic imaging, Skeletal trauma, Visualization, Forensic analysis.

Abbreviations
CT: Computed Tomography, CR: Cinematic Rendering, 3D: Three-Dimensional, XR: X-Ray, MRI: Magnetic Resonance Imaging, VR: Volume Rendering, MPR: Multi-Planar Reconstruction.

Introduction
Forensic imaging is vital for analyzing skeletal trauma and determining injury cause, manner, and timing. Traditional techniques like X-Ray, CT, and MRI have limitations in depicting complex injuries. Cinematic rendering (CR) has emerged as a promising method, offering photorealistic 3D visualization of anatomy and pathology. Unlike traditional imaging methods that generate images based on X-ray attenuation or signal intensity, CR utilizes advanced algorithms to simulate the interaction of light with anatomical structures, resulting in visually striking and realistic representations. This article explores CR's potential in transforming forensic imaging, examining its advantages over traditional methods, and its impact on the field. CR's ability to create immersive 3D renderings aids in understanding injury patterns, especially in complex cases. Its interactivity allows real-time exploration of trauma sites, aiding event reconstruction. CR could revolutionize forensic communication in court, conveying complex findings effectively [1-6].

The Radiologic 3D Cinematic Rendering Technique combines radiological data and advanced visualization algorithms to create detailed 3D representations. The technique follows a workflow, beginning with high-resolution imaging data acquisition followed by segmentation, and rendering to produce accurate models. This method finds applications in medical education, surgical planning, and clinical presentations, enhancing diagnostic accuracy, treatment planning, and communication.

The purpose of this article is to explore the potential of CR in transforming forensic imaging and assess its impact on the analysis of skeletal trauma. By examining the advantages and capabilities of CR over traditional radiological techniques, we can gain insight into the potential benefits it offers to forensic experts and the field as a whole. CR's ability to produce photorealistic

3D renderings of skeletal trauma holds significant promise. By providing a more immersive and detailed visualization, CR allows forensic experts to better understand the injury patterns and characteristics. This enhanced visualization aids in the accurate identification and characterization of skeletal injuries, even in cases involving complex fractures or subtle trauma that may be challenging to interpret using conventional imaging methods alone [7-11]. Despite its advantages, CR has limitations. Computational complexity may hinder real-time visualization, and accuracy in representing structures can be imperfect due to factors like noise and limitations in resolution. Interpretation could be subjective, impacting standardization. Accessibility might be limited due to specialized hardware and software requirements. Ongoing research aims to address these challenges, potentially leading to broader adoption of CR in clinical practice.

In summary, CR's potential in transforming forensic imaging for skeletal trauma analysis is explored. Its advantages over traditional methods and photorealistic 3D visualization offer a promising avenue for improved accuracy. The article delves into methodologies, results, and discussions surrounding CR's application in skeletal forensic imaging, presenting its capabilities and potential impact.

Methods and Materials

Imaging Technique

At our institution, all postmortem CT exams are performed according to a standardized protocol (Table 1) using a 128-slice multidetector CT Somatom Definition AS (Siemens Healthineers AG, Erlangen, Germany). The acquired data is reconstructed into axial bone and soft tissue images with a slice thickness of 0.6 mm. Sagittal and coronal reformations are stored at a slice thickness of 1 mm. More complex reconstructions (oblique or curved planes, 3D VR Reconstructions, etc.) can be extracted from the stored thin-slice images later if needed. This protocol can be flexibly adapted to specific research questions or regions can be supplemented or selectively investigated.

Post-processing Techniques for Cinematic Rendering

We utilized dedicated workstations equipped with the Cinematic Rendering package for image reconstruction. This product is commercially available and is used by us for image reconstruction purposes. Image rendering was performed using syngo.via version 8.7 and the syngo.via Enterprise Browser (Siemens Healthineers, Erlangen, Germany). The initial raw datasets, as discussed in the imaging technique section, were imported into the program to perform subsequent reconstructions such as MPR (Multi-Planar Reconstruction), VRT (Volume Rendering Technique), or Cinematic Rendering with optimal display and quality.

Visualization Capabilities Surpassing Traditional Imaging Methods

In the field of radiology, the advancements in imaging technology have paved the way for innovative visualization techniques that enhance the interpretation and communication of medical imaging data. Among these techniques, CT cinematic rendering and volume rendering are prominent methods utilized for the visualization of anatomical structures and pathologies. While both approaches aim to improve the visualization of CT scans, they differ in their underlying principles and the visual information they provide.

CT Cinematic Rendering

CT cinematic rendering is a relatively new technique that leverages advanced algorithms and computational power to create highly realistic visualizations from CT scan data. By simulating the interaction of light with tissues, cinematic rendering produces visually immersive images that closely resemble real-world appearances. It captures fine details such as surface textures, shading, and subtle changes in tissue density, resulting in lifelike renderings that aid in the understanding and interpretation of anatomical structures. CT cinematic rendering provides enhanced depth perception, allowing for interactive exploration of the scanned anatomy from multiple angles and perspectives (Figure 1,2).

Volume Rendering

Volume rendering, on the other hand, is a well-established technique used in CT imaging for visualizing volumetric data. It involves the direct rendering of the raw voxel data obtained from CT scans, using transfer functions and rendering algorithms to transform the data into a 3D representation. By assigning color and opacity to different tissue densities, volume rendering enables the visualization of internal structures and highlights anatomical abnormalities. It provides insights into the spatial relationships and distribution of tissues within the volume, aiding in the detection and characterization of pathologies. Volume rendering offers flexibility in adjusting the transparency and color mapping, allowing radiologists to optimize the visualization for specific diagnostic purposes. Compared to traditional imaging methods such as volume rendering and surface rendering, 3D cinematic rendering offers a transformative visual experience. By simulating the interaction of light with different tissues and materials within the human body, it creates visually stunning renderings that closely resemble the actual anatomical structures. The resulting images exhibit lifelike textures, shadows, and reflections, enabling clinicians to gain a deeper understanding of the complex spatial relationships and anatomical variations. Despite its numerous benefits, it is important to acknowledge certain limitations of 3D cinematic rendering. The computational complexity and time-consuming nature of generating highly realistic renderings can

Table 1: Post mortem Computed Tomography Scan Protocol.

Region	Tube Voltage (kVp)	Reference Tube current (mA)	Care Dose 4D / Care kV	Field of View (mm)	Collimation (mm)	Pitch factor	Rotation time (s)
Head and Neck	120	350	on / off	300	40x0.6	0.35	1
Body and extremities	120	500	on / on		128x0.6	0.35	1

impact workflow efficiency, particularly in time-sensitive clinical scenarios. Validation and verification against gold standard imaging techniques are crucial to ensure accuracy and reliability. Moreover, the interpretation of cinematic rendering images may be subjective and dependent on the expertise and experience of the user, necessitating ongoing efforts for standardization and training.

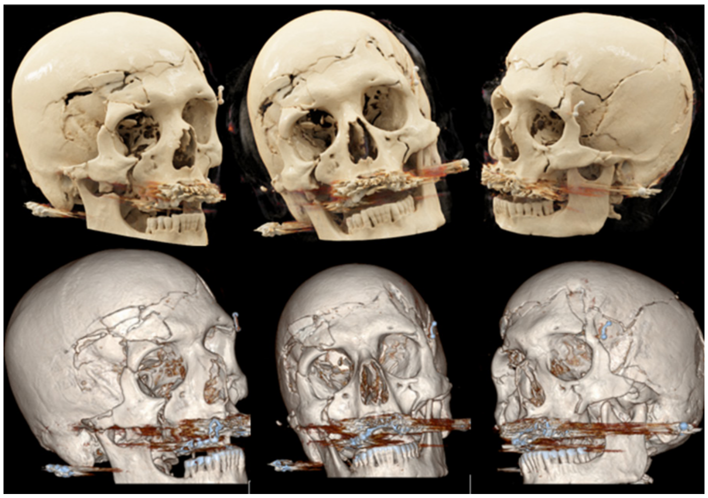

Figure 1: Multiple fractures of the midface as well as the fronto-temporo-parietal skull cap with significant emphasis on the frontal bone, within the context of a severe blunt force traumatic brain injury. In the upper row, the reconstructions of cinematic rendering are shown, which, in comparison to the reconstructions of VRTs in the lower row, depict the fractures in much more detail and clarity. Overall, cinematic rendering provides a much more realistic visual impression.

Figure 2: Extensive osseous destruction of the entire skeletal system with deformation of the bony thorax, spine, extremities, and cranial vault, resulting from a suicide attempt by jumping in front of a train. On the left side, the VRT (Volume Rendering Technique) reconstruction, and on the right side, the cinematic rendering.

Multidimensional Exploration of Skeletal Trauma

The enhanced visualization capabilities of 3D cinematic rendering facilitate a more thorough examination and understanding of spatial relationships within a forensic scene. This multidimensional format allows investigators to explore different angles, aiding in better reconstruction and visualization of the crime scene, identifying patterns, and conveying complex forensic findings in court.

In the forensic context, visualizing skeletal trauma is crucial for reconstructing events, determining the cause of death, and expert testimony. Traditional methods like 2D radiographs and CT scans have limitations in representing the complex three-dimensional nature of trauma and spatial relationships. 3D cinematic rendering captures fractures, dislocations, and foreign objects, offering a comprehensive view of trauma. An advantage is its interactive exploration, allowing forensic experts to dynamically rotate, zoom in, and examine the trauma site. This aids in understanding spatial relationships, fracture patterns, bone fragments, and soft tissue damage. Such exploration assists in reconstructing the sequence of events, determining the cause and manner of death (Figure 3-5).

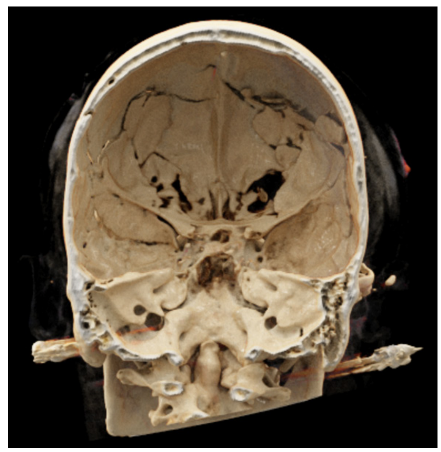

Figure 3: Cinematic rendering of an extensive cranial brain injury with multiple impression fractures of the frontal bone. Dorsal view through the cranial vault towards the frontobase.

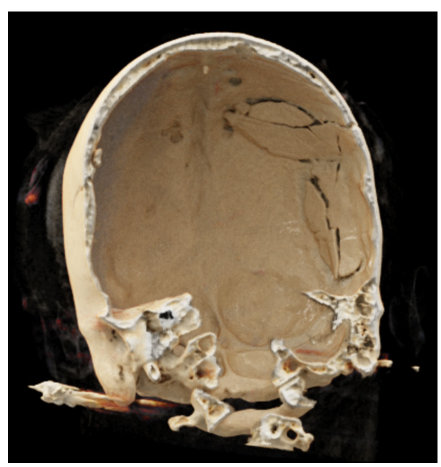

Figure 4: Same case as in Figure 3: Cinematic rendering of extensive impression fractures of the left parietal cranial vault. Ventral view.

Figure 5: Multifocal fractures of the trunk with bilateral series rib fractures, transsection and dislocation of the thoracic spine, as well as multiple avulsion fractures of the right-sided lumbal transverse processes. The conventional CT images on the left side and in the middle can only depict the fractures in one plane or at one location. The cinematic rendering on the right side represents the multiple fractures in their entirety and complexity.

Highly Realistic Visualizations with Cinematic Rendering

The advantage of 3D cinematic rendering in forensic imaging lies in its lifelike precision when recreating evidence. By incorporating the aforementioned realistic lighting, shadows, and textures, the rendered images closely mimic the actual crime scene or object, aiding in understanding spatial relationships, identifying patterns, and drawing conclusions about evidence.

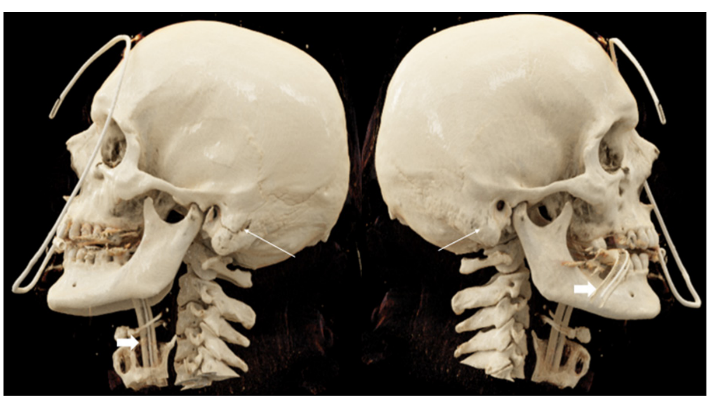

Figure 6: Left side, lateral view: Cinematic Rendering of a subtle fracture of the petrous bone with a delicately delineated fracture and fracture-related occlusion of the external auditory canal.
Right side, lateral view: Cinematic Rendering of the normal anatomy of the petrous bone with well-defined external auditory canal.
Thick arrows: Tracheal tube.

This realism enhances event recreation and visualization in forensic investigations. Dynamic, multidimensional visualizations allow exploration of various angles, aiding in reconstructing the sequence of events, identifying potential causes, and determining the manner of death. This realistic approach also improves evidence presentation in court, resulting in more compelling and accurate forensic findings (Figure 6,7).

Figure 7: Cinematic rendering from dorsal (left) and ventral (right) views: Multifocal skeletal injuries resulting from a rollover trauma caused by an excavator. Right-sided series rib fractures, disruption of the left iliosacral joint, fracture of the upper and lower pubic rami on the left, fracture of the lower pubic ramus on the right, fracture of the right acetabulum, distal femur fracture on the right with significant dislocation and mid-shaft fracture of the right fibula and tibia with 180-degree torsion (note the misrotated right foot).

Results

The systematic pictorial review conducted on the application of cinematic rendering (CR) in skeletal trauma analysis revealed several significant findings. These findings highlight the advantages of CR over conventional imaging and rendering methods and underscore its potential for transforming forensic imaging practices.

One key finding is that CR provides superior visualization capabilities compared to traditional imaging techniques. By leveraging advanced algorithms and rendering techniques, CR generates highly detailed and realistic visualizations of skeletal trauma. These visualizations surpass the limitations of conventional imaging methods, such as computed tomography (CT) and magnetic resonance imaging (MRI), in terms of their ability to accurately depict complex skeletal injuries. The enhanced level of detail and accuracy offered by CR enables forensic experts to identify and assess skeletal injuries with unprecedented precision. Furthermore, CR allows for interactive exploration of the trauma site from various angles. Forensic experts can manipulate the rendered images and examine the trauma scene from different perspectives. This interactive feature of CR contributes to a comprehensive understanding of the injury pattern by providing a multi-dimensional view of the trauma site.

Another notable finding is that CR enables the creation of highly realistic visualizations. The photorealistic nature of CR-generated images enhances the comprehension of complex forensic findings for both experts and non-experts, including legal professionals. The highly detailed and visually engaging nature of CR visualizations facilitates effective communication of findings in the courtroom. This improved communication of findings enhances the impact and credibility of forensic evidence, potentially influencing legal outcomes.

Conclusion

The incorporation of CR in forensic imaging offers numerous advantages. Its ability to produce photorealistic 3D renderings enhances the spatial comprehension of skeletal trauma, leading to improved accuracy in injury identification and characterization. CR also enables the visualization of subtle fractures and complex injury patterns that may be challenging to interpret using traditional imaging methods alone. Moreover, the interactive nature of CR allows for real-time manipulation and exploration of the trauma scene, providing valuable insights into injury dynamics and possible mechanisms.

Cinematic rendering represents a significant advancement in forensic imaging for the analysis of skeletal trauma. Its enhanced visualization capabilities, coupled with its ability to accurately depict complex injury patterns, make it a valuable tool for radiologists and forensic experts in their analysis and interpretation. With further development and integration into routine forensic practice, CR has the potential to revolutionize the field, improving the accuracy and reliability of skeletal trauma analysis, and ultimately facilitating justice through robust forensic evidence.

References

1. Spies AJ, Steyn M, Prince DN, et al. Can forensic anthropologists accurately detect skeletal trauma using radiological imaging? Forensic Imaging. 2021; 24: 200424.
2. Obertova Z, Leipner A, Messina C, et al. Postmortem imaging of perimortem skeletal trauma. Forensic Sci Int. 2019; 302: 109921.
3. Dappa E, Higashigaito K, Fornaro J, et al. Cinematic rendering - an alternative to volume rendering for 3D computed tomography imaging. Insights Imaging. 2016; 7: 849-856.
4. Eid M, De Cecco CN, Nance JW Jr, et al. Cinematic Rendering in CT: A Novel, Lifelike 3D Visualization Technique. AJR Am J Roentgenol. 2017; 209: 370-379.
5. Soyer P. Cinematic rendering: When virtuality comes true. Diagn Interv Imaging. 2019; 100: 465-466.
6. Johnson PT, Schneider R, Lugo-Fagundo C, et al. MDCT Angiography With 3D Rendering: A Novel Cinematic Rendering Algorithm for Enhanced Anatomic Detail. AJR Am J Roentgenol. 2017; 209: 309-312.
7. Berger F, Ebert LC, Kubik-Huch RA, et al. Application of Cinematic Rendering in Clinical Routine CT Examination of Ankle Sprains. AJR Am J Roentgenol. 2018; 211: 887-890.
8. Rowe SP, Fritz J, Fishman EK. CT evaluation of musculoskeletal trauma: initial experience with cinematic rendering. Emerg Radiol. 2018; 25: 93-101.
9. Rowe SP, Zinreich SJ, Fishman EK. 3D cinematic rendering of the calvarium, maxillofacial structures, and skull base: preliminary observations. Br J Radiol. 2018; 91: 20170826.
10. Chu LC, Rowe SP, Fishman EK. Cinematic rendering of skin and subcutaneous soft tissues: potential applications in acute trauma. Emerg Radiol. 2019; 26: 573-580.
11. Boven J, Boos J, Steuwe A, et al. Diagnostic value and forensic relevance of a novel photorealistic 3D reconstruction technique in post-mortem CT. Br J Radiol. 2020; 93: 20200204.