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Research Article

Information Acquisition and Seismic Damage Prediction of Masonry Structures in Rural Areas Based on UAV Inclined Photogrammetry

Chao Kong [1], Arthit Petchsasithon [2*]

[1] Master student, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand
[2] Assistant Professor, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand
* **Corresponding Author:** arthit.pe@kmitl.ac.th

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ABSTRACT

Using a novel methodology that integrates incremental dynamic analysis (IDA) and unmanned aerial vehicle positioning (POS) analysis, this study aims to assess the seismic risk of brick structures in rural China. This method can collect a lot of data and accurately anticipate seismic damage by combining UAV oblique photography with IDA analysis. Because rural China has many masonry structures, the project will design unique seismic risk mitigation strategies. High-resolution cameras on Unmanned Aerial Vehicles capture realistic photographs of rural brick buildings. The collected data is carefully examined to reveal architectural and structural elements. The project uses dynamic post-processing software from the CHC Geomatics Office to improve UAV-reference station position accuracy. This program analyzes UAV POS data disparities. The findings allow rural Chinese brick buildings to be assessed for seismic sensitivity during unexpected ground shaking occurrences. UAV tilt-photography reduces manpower and expenditures, improving inquiry efficiency. This combination improves seismic risk response. The IDA and UAV POS analysis are essential for earthquake preparedness and risk mitigation. This data-driven method informs lawmakers, urban planners, and disaster management authorities worldwide, improving earthquake engineering and catastrophe resilience programs. This work improves seismic threat assessment and masonry structure fortification, making earthquake-prone buildings safer. Thus, rural communities benefit from it.

Keywords: Masonry Structure, Building Information Acquisition, Seismic Damage Prediction, UAV Inclined Photogrammetry, Incremental Dynamic Analysis.

INTRODUCTION

Earthquakes damaged nearby communities and infrastructure. Global seismic activity measurement and reduction systems are essential (Freddi et al., 2021). Rural China, where brick constructions have long been oversupplied, is especially affected. Previous research by Yating Zhang, Fung, Johnson, and Sattar (2022) revealed these structures are seismically vulnerable. C. Wang, Si, Zhang, Cao, and Canbulat (2021) use the 2008 Wenchuan, Sichuan earthquake to demonstrate how earthquakes can destroy rural settlements. According to Aydogdu, Demir, Comert, Kahraman, and Ilki (2023), earthquake-prone areas with many brick buildings need new methods to quickly and accurately identify seismic activity dangers and reduce risks.

Infrastructure evaluation and catastrophe risk management have increased with the introduction of Unmanned Aerial Vehicles (UAVs), or drones. Utkucu, Kurnaz, and İnce (2023) assert that seismic risk assessment could be revolutionized by Utilizing Unmanned Aerial Vehicles (UAVs) equipped with high-resolution cameras and other cutting-edge imaging technology. Detailed visual renderings of masonry projects and their spatial layout can achieve this, according to Ansari, Rao, and Jain (2023). According to Jena and Pradhan (2020), more people are Using Unmanned Aerial Vehicles (UAVs) for structural evaluation since they can improve our understanding of rural seismic sensitivity and increase seismic risk. In spite of its many benefits, unmanned aerial vehicle technology is still being studied for structural analysis and seismic risk assessment (Wankmüller, Kunovjanek, & Mayrgündter, 2021). This approach must be tested for seismic vulnerability evaluations, according to A. Rejeb, K. Rejeb, Simske, and Treiblmaier (2021) and J. Wang and Ueda (2023b). A data-driven, technology-enhanced framework for analyzing and managing rural China seismic hazards is the goal of this project.

To improve seismic risk assessment, this research examines the smooth integration of UAV technology with structure analysis methodologies. Especially Burdziakowski (2020) and Greco, Barca, Raumonen, Persia, and Tartarino (2023). Inclination photography using UAVs is an interesting technology that has received attention. This study investigates the viability of extracting structural component information and constructing a real-time three-dimensional model using images acquired by Unmanned Aerial Vehicles (UAVs). Two reliable seismic performance assessment methods are incremental dynamic analysis and finite element numerical simulation. Technological solutions may improve earthquake vulnerability assessment, according to this study.

The aforementioned finding possesses substantial implications that transcend the confines of rural China. Global earthquake dangers require novel risk assessment and mitigation approaches. In non-rural China, UAVs and structural analysis can alter seismic risk assessment (Cui et al., 2022; Euchi, 2021). This study investigates how technology may impact risk mitigation and disaster preparedness in rural China and other earthquake-prone regions. To increase earthquake resilience and safety, we will examine the complex relationship between modern technology and traditional traditions.

LITERATURE REVIEW

S. Wang et al. (2022) report that civil engineers are increasingly using UAVs to predict seismic damage and analyze construction stability. This method has several benefits, especially in rural China where brick buildings are ubiquitous and earthquake-prone (Soleymani, Jahangir, & Nehdi, 2023). Masonry constructions are more seismically sensitive in particular regions due to their material and architectural features, according to Rachmawati and Kim (2022). Conventional methods for examining these structures are restricted. Remote areas may not be able to accommodate time-consuming and expensive on-site exams (Sharma et al., 2021). UAV-based inclination photogrammetry has revolutionized data collection because of its non-invasive, cost-effective, and efficient nature. This technique allows for detailed seismic risk assessment of masonry constructions.

China is ideal for unmanned aerial vehicle photogrammetry and seismic damage prediction due to its high seismic activity (Levine & Spencer Jr, 2022). Primitive masonry has long been prevalent in rural regions. Seismic events threaten infrastructure and people, necessitating new methods for assessing masonry structure structural integrity (Shareef, 2023). Menna et al. (2022) suggest that inclined photogrammetry-equipped UAVs could increase data collecting accuracy and velocity. Engineers and academics can then perform detailed structural evaluations and better forecast damage. Understanding how this technology can be used in rural China is essential for improving seismic risk assessment and catastrophe prevention.

UAV Technology Advancements for Seismic Risk Assessment

Drones, or Unmanned Aerial Vehicles (UAVs), have improved tremendously and are now vital for seismic risk assessment (T. Li & Hu, 2021). Yao, Qin, and Chen (2019) report that recent technological advances have improved earthquake-prone data gathering, processing, and evaluation. Some developments in UAV technology require sensors and payloads to gather high-resolution photos, LiDAR data, and thermal imaging. These sensor technologies increase seismic vulnerability detection by detecting even modest structural anomalies and surface deformations, according to Giordan et al. (2020). J. Wang and Ueda (2023a) state that rapid capture and processing of huge datasets speeds damage assessment and facilitates mitigation strategy development. Rapid decision-making before and after earthquake disasters is possible thanks to real-time data transmission, according to Mishra and Singh (2023). Technological advances have made seismic risk assessment more complete and eliminated the necessity for on-site inspections in dangerous or remote sites, reducing human assessor risk (Ying Zhang, Guo, Yin, Zhao, & Lu, 2023).

Kumar et al. (2023) report that machine learning and AI have greatly improved unmanned aerial vehicle seismic risk assessment accuracy. UAVs can process and analyze massive volumes of data from various technologies to make more accurate and fast structural damage forecasts (Feroz & Abu Dabous, 2021). Machine learning algorithms detect building deterioration symptoms like fractures, displacements, and stress concentrations. Engineers can better assess a structure's seismic risk (Hussain et al., 2022; Parra & Guerrero, 2020). AI-powered data fusion systems combine sensor data to improve evaluation. With machine learning and UAV technology, seismic data, structural features, and environmental variables can be used for predictive modeling (Caroti, Piemonte, & Squeglia, 2022). This allows earthquake damage predictions for structures and critical infrastructure. Improvements in disaster preparedness and risk mitigation approaches save lives and reduce economic damages (Dindaroğlu et al., 2022). Artificial intelligence approaches like fuzzy reasoning and deep learning speed up building data collection. Deep learning can assess 3D models and drone photos to determine structure style and storey count. Using engineering experience, local conditions, and traditional construction codes creates practical standards. G. Li, Zhang, Dong, and Yu (2022) say the criteria help reveal interior wall layouts, building construction complexity, material attributes, wall reinforcement, and other important details. **Figure 1** below demonstrates the basic structure of seismic damage prediction.

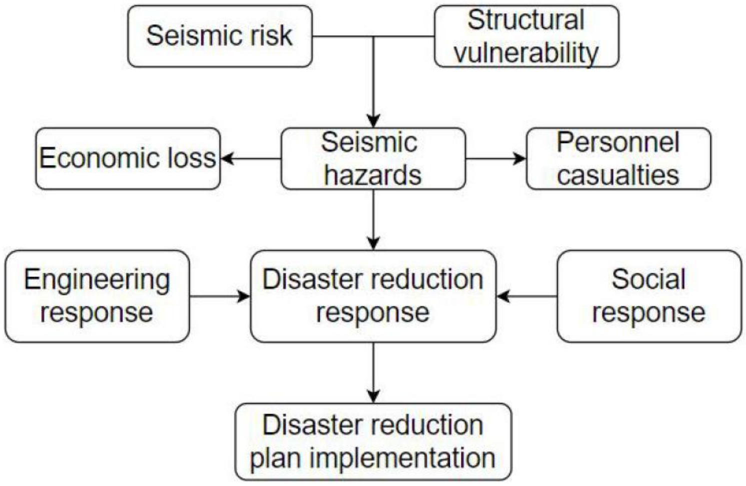

Figure 1. Basic Structure of Seismic Damage Prediction

Chen, Reichard, Xu, and Akanmu (2023) report that contemporary software and modeling tools combined with unmanned aerial vehicle technologies allow three-dimensional structural analysis and mapping. Hussain et al. (2022) state that Structure-from-Motion (SfM) and photogrammetry software may create three-dimensional models from UAV images. These models show building conditions in detail. Giordan et al.'s 2020 study found that this helps engineers detect vulnerabilities, comprehend structure geometry, and estimate seismic effects on buildings. Computer programs like Finite Element Analysis (FEA) build complicated structural models that depict how sections behave during seismic events. Using UAVs and these software tools, specialists can design a seismic risk assessment strategy. The structure's attributes, earthquake susceptibility, and damage risk are included. UAV, sensor, machine learning, and sophisticated software have ushered in a new seismic risk assessment era, according to Chen et al. (2023). This level boosts efficiency, accuracy, and data use. These advancements allow researchers, engineers, and disaster management authorities to mitigate seismic hazards, reduce damage, and protect sensitive areas (Cui et al., 2022). New technology can assist Unmanned Aerial Vehicles (UAVs) in identifying seismic hazards, boosting earthquake prognoses.

Structural Vulnerability Assessment of Rural Masonry Buildings

Figure 2-d demonstrates that rural masonry buildings are everywhere, necessitating structural vulnerability assessments (Soleymani et al., 2023). Cattari, Angiolilli, Alfano, Brunelli, and De Silva (2022) suggest these buildings may not meet metropolitan building technology and strengthening standards. These structures use local clay bricks and stones. Seismic activity can kill people and ruin rural masonry homes. Effective disaster preparedness and mitigation need vulnerability assessment. According to Godínez-Domínguez et al. (2021) and Guzmán, Fóster, Ramírez-Correa, Grandón, and Alfaro-Perez (2018), typical evaluation procedures include field surveys and visual inspections. Inspections and surveys take time and are error-prone. Nikolić, Runjić, Ostojić Škomrlj, and Benvenuti (2021) propose that the use of UAV-based inclination photogrammetry and non-destructive testing can simplify structural risk analysis.

Figure 2. Structure Types of Villages Buildings

UAVs can improve rural structural development data collection. A solid foundation for structural vulnerability evaluations. Researchers and engineers can take detailed photographs of buildings from different angles utilizing UAVs with inclination photogrammetry. This lets you generate realistic three-dimensional models and spot structural faults that visual inspection might overlook. Cracks, deformations, and other faults can be automatically recognized using this data, advanced image processing, and machine learning (Soleymani et al., 2023). UAVs can better assess rural masonry constructions since they can reach hard-to-reach regions. Photogrammetry, seismic testing, and GPR can assess structure stability. These approaches assess foundation stability and material composition (Stepinac et al., 2021). Godínez-Domínguez et al. (2021) suggest that improved technology helps study rural masonry constructions in detail. Targeted retrofitting and strengthening may make structures seismically vulnerable. Technology can help rural masonry house owners prepare for catastrophes and reduce risk by spotting structural issues.

Seismic Risk Mitigation in Rural China

China's rural areas have numerous earthquake-prone brick buildings, therefore decreasing earthquake risk is vital (Hobbs et al., 2023). China has seen huge earthquakes like the 2008 Wenchuan. This emphasizes urban and rural earthquake mitigation (Adhikari & D'Ayala, 2020). Rural seismic risk mitigation is difficult due to resource and experience shortages. According to Chaudhary and Piracha (2021), rural Chinese masonry structures lack seismic-resistant materials, making them vulnerable to large earthquakes. Işık et al. (2022) propose a multidisciplinary approach combining engineering, community participation, legislative initiatives, and cutting-edge technology to address this issue.

Fortifying and renovating rural Chinese brick homes lowers earthquake risk (Oliveira, 2022). Bracing, foundation reinforcement, and seismically resistant materials reduce structure sensitivity (Furtado, 2020). Community-based projects receive awareness, training, and financial incentives from government and foreign programs (Elliott, 2020). These activities help rural home improvements. According to Adhikari and D'Ayala in

2020, rural seismic risk mitigation needed sharing earthquake-resistant building methods and materials. Işık et al. (2022) recommend using local materials and detailed construction instructions to help residents make informed judgments about home remodeling. Modern remote sensing and UAV-based inclination photogrammetry could reduce rural China's earthquake risk. Year 2020 These tools evaluate risk-reduction efforts and identify vulnerable systems. Together, these methods and strong policy institutions and community involvement lower seismic risk and increase rural China's earthquake resistance.

METHOD

The Incremental Dynamic Analysis (IDA) technique stands out as a pivotal method for seismic risk assessment. It involves multiple elasto-plastic dynamic time-range analyses via finite element numerical simulations. These analyses establish the correlation between the intensity index of ground shaking (IM) and the structural Damage Index (DM). To mitigate the stochasticity inherent in traditional time-range analyses, various ground shaking records are utilized. This study's essence lies in integrating advanced Unmanned Aerial Vehicle (UAV) technology and employing CC (Context Capture Center) software as the primary platform for 3D modeling. This integration aims to gather structural building information essential for IDA and subsequently assess the seismic vulnerability of structures. The methodology specifically targets challenges associated with seismic risk in rural China, emphasizing masonry structures as a primary focus area.

The HuaCe V200 quadcopter UAV (**Figure 3-a**) is equipped with the RuiBo D2M half-frame tilt high-resolution aerial camera (**Figure 3-b**), leading the way in data acquisition technologies. Deployed in representative rural areas across China, this UAV tilt photography system autonomously conducts multi-view tilt photography of masonry structures, a crucial component of the seismic risk assessment process. The UAV's flight system integrates flight control, communications, power, and sensor components, enabling seamless navigation along predetermined routes for precise data acquisition. Geo-referenced images, collected and processed using photogrammetric software and computer vision techniques, contribute to the generation of detailed three-dimensional models. Furthermore, this process provides essential building information, encompassing details about geometry, materials, and the identification of structural defects.

(a) HuaCe V200 Quadcopter UAV

(b) RuiBo D2M Half Frame Tilt Camera

Figure 3. UAV Inclined Photography System

Renowned for its redundancy, self-diagnostic algorithms, and a dependable 100Hz image-free control differential system, the HuaCe V200 UAV caters to a broad spectrum of applications, spanning from mapping to security surveillance. Its technical specifications are detailed in **Table 1**. The D2M tilt camera, boasting a 1.3-megapixel high-resolution capability, offers compactness ideal for aerial imaging purposes. Its adjustable shutter speed, ample memory capacity, high synchronization accuracy, and diverse control modes render it remarkably adaptable for capturing precise and detailed images. Furthermore, the camera's unique lens arrangement and viewing angle amplify its suitability across various environmental conditions, meeting the imaging objectives of the study. Its technical parameters are also presented in **Table 1**.

Table 1. List of Technical Parameters of the Vehicle and Inclined Camera

Items	**Parameters**
UAV Technical Parameters	
Wheelbase	653mm
Overall dimensions	885x902x340mm 500x518x140mm
Weight	3.06kg(with batteries)
Maximum take-off weight	5.16kg
GNSS	GNSS BDS B1/B2; GPS L1/L2; GALILEO E1/E5b; QZSS L1/L2
Positioning accuracy (RMS)	vertically: ±2.5m (GNSS single point); ±0.8m (DGPS); ±1.5cm+1ppm (RTK) standards: ±1.5m (GNSS single point); ±0.4m (DGPS); ±1.0 cm+1ppm (RTK)
Orientation accuracy (RMS)	0.45°
Maximum rise/fall speed	6m/s
Maximum horizontal flight speed	20m/s(manual flight)
Maximum flight altitude	7000m
Forward radar operating frequency	77-81GHz
Forward radar range	0.5-60m
Tilt Camera Technical Parameters	
Total pixels	1.3 hundred million
Product size	104.5*104.5*87mm
Product weight	≤630g
Exposure time interval	0.5s
Shutter speed	1/100-1/2000s
Camera memory	640GB*2
Data copy mode external storage	high-speed download
Mounting method	Lifting/Under Bracket Mount
Shock absorption	Shock absorbing ball
Working environment	-20°C-65°C
Trigger signal	Skyport/Low Level/Serial Port
Optical focal length	25mm/35mm
Number of lenses	5
Lens tilt angle	45°
Lens layout	Surround
Closest focus distance	8m/10m
FOV viewing angle (Horizontal)	50.35°/37.12°
FOV viewing angle (Vertical)	34.66°/25.13°

Note: The endurance of a cruise outside the ground-effective area at a speed of 10 m/s to the ground under static airflow atmospheric conditions with a barometric pressure of 101.325 KPa and a temperature of 20°C when the power supply is completely depleted.

In addition, the research briefly employs the CGO (CHC Geomatics Office) dynamic post-processing software for POS data differential resolution, aiming to calculate dynamic relative positions and determine absolute coordinates between the UAV and reference stations. The software serves as a comprehensive post-processing tool, aiding in the extraction and analysis of essential data for the research (**Figure 4**).

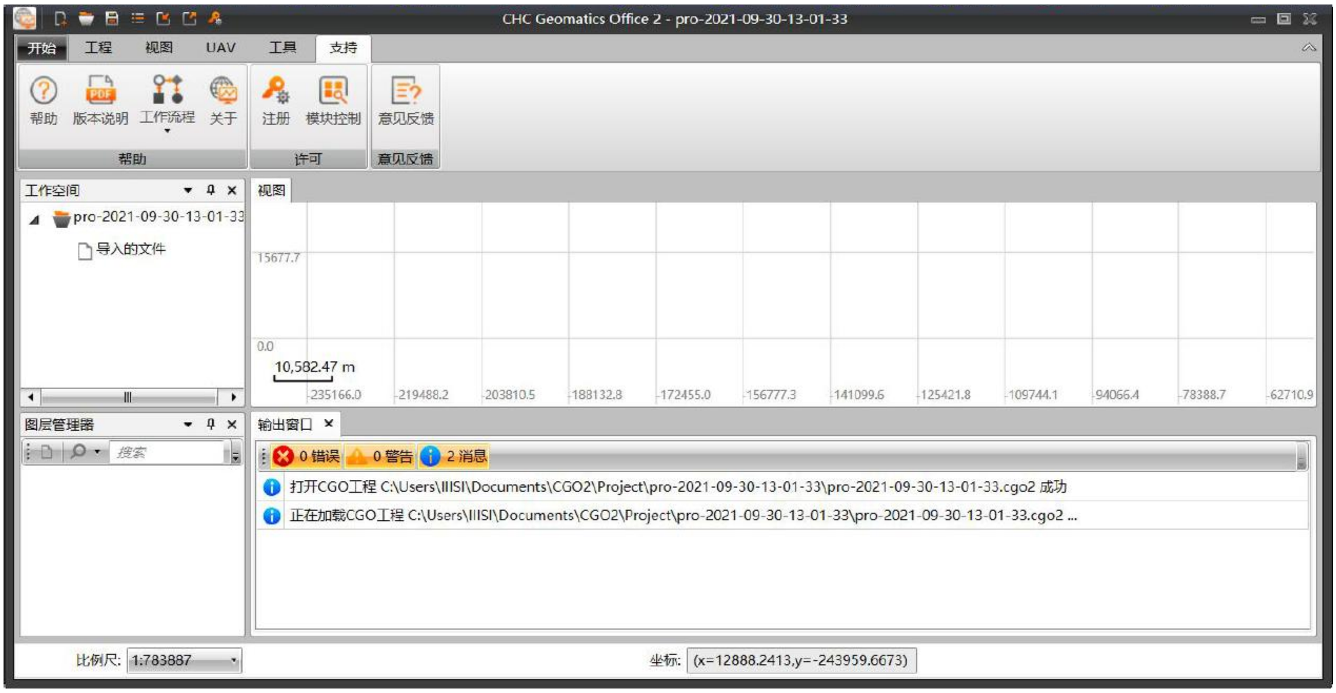

Figure 4. UAV POS Data Difference Calculation

In photogrammetry, it is common to establish a mathematical relationship of the image to describe the geometric relationship between the ground point and the image point. This established mathematical expression is known as the covariance equation. In the covariance equation, the covariance condition is often expressed in terms of and Two space vectors are used and $SA = \lambda Sa$. In the equation of the co-linearity condition, X_S、Y_S、Z_S are the coordinates of ground point A in the coordinate system of the camera station, and the actual coordinates of ground point A are X, Y, Z, and satisfy:

$$\mathrm{x} - \mathrm{x}_0 + \Delta \mathrm{x} = -\mathrm{f}\,\frac{\mathrm{a}_1(X - X_s) + \mathrm{b}_1(Y - Y_s) + \mathrm{c}_1(Z - Z_s)}{\mathrm{a}_3(X - X_s) + \mathrm{b}_3(Y - Y_s) + \mathrm{c}_3(Z - Z_s)}$$

$$\mathrm{y} - \mathrm{y}_0 + \Delta \mathrm{y} = -\mathrm{f}\,\frac{\mathrm{a}_2(X - X_s) + \mathrm{b}_2(Y - Y_s) + \mathrm{c}_2(Z - Z_s)}{\mathrm{a}_3(X - X_s) + \mathrm{b}_3(Y - Y_s) + \mathrm{c}_3(Z - Z_s)}$$

The covariance equation has various forms of expression, but its meaning is the same, and the equation is one of the common expressions, which is widely used in photogrammetry and plays an important role in determining the spatial position of ground points. In addition, the covariance equation is usually used as a mathematical model for the air-three beam method of levelling when performing air-three levelling, and it is also used as a mathematical basis for back-calculating coordinates.

Building upon the aforementioned theory, the CC (Context Capture Center) real scene modeling software, as depicted in **Figure 5**, is embraced. This software operates through a spatial framework within the 3D model and processing settings, enabling the generation of various formats of the real scene 3D model (such as OBJ format, OSGB format, DAE format, etc). The software employs an automated 3D modeling system, characterized by straightforward modeling procedures. It facilitates the automatic creation of tilted 3D models, requiring no manual intervention throughout the entire modeling process. Notably, this system ensures rapid model processing while effectively utilizing simple continuous images to generate highly realistic and immersive live 3D scene models.

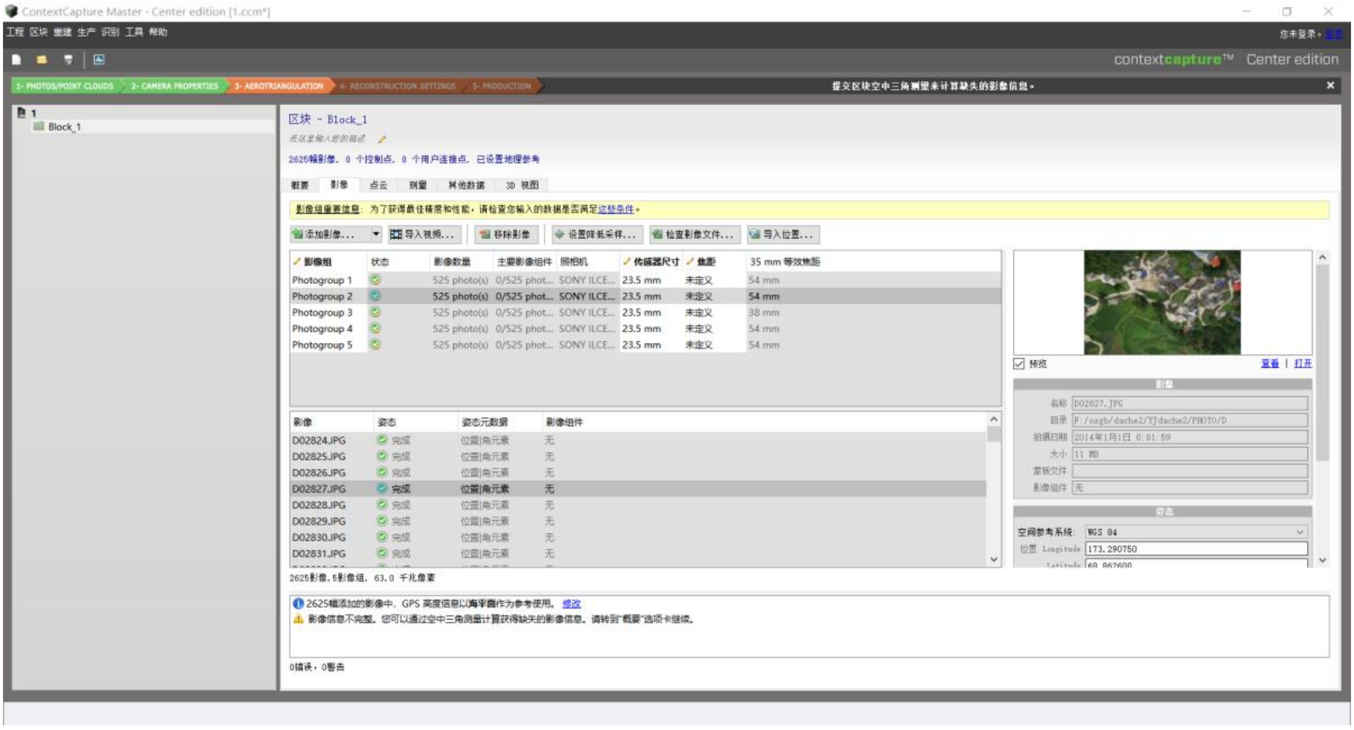

Figure 5. CC (Context Capture Center) Reality Modelling Software

Building information must be extracted to give input data and key aspects for building mechanical analysis. Researchers and engineers can better understand building structure and behavior with this approach, making structural analysis, design, and maintenance more reliable. It guarantees long-term project safety and durability. The UAV tilt-photography data used to create real-life 3D models meets building dimension accuracy standards through clarity and resolution. You can quickly learn about village construction objects using deep learning and fuzzy reasoning. These methods provide useful geometric appearance data. Geometric measures, floor counts, structural categories, and other characteristics are included. Moreover, they efficiently unveil hidden information like internal wall arrangements, construction measures, material properties, and wall reinforcement, significantly aiding in comprehensive building analysis.

The seismic vulnerability of a structure can be forecasted by establishing a mechanical analysis model based on the aforementioned building information. This model employs the incremental dynamic analysis (IDA) method to scrutinize the structure's susceptibility to seismic forces. Seismic vulnerability refers to the anticipation of structural damage during an earthquake, often represented as a probability of surpassing a certain threshold. The expression for seismic vulnerability can be formulated as follows:

$$P_{DV-IM}(0 \mid PGA) = \sum P_{DV-LS}(0 \mid C) P_{DV-IM}(Z > C \mid PGA)$$

Where $P_{DV-IM}(0 \mid PGA)$ is the probability that the structure reaches its limit state under a specific peak acceleration PGA, i.e., the probability of exceedance; $\sum P_{DV-LS}(0 \mid C)$ represents the probability that the structure reaches its limit state at a specific seismic capacity C, i.e., the structural capacity analysis; and $P_{DV-IM}(Z > C \mid PGA)$ is the probability that the structure's seismic response, Z, is greater than its seismic capacity, C, under a specific peak acceleration, PGA, i.e., the analysis of the structure's seismic demand.

RESULTS AND ANALYSIS

The comprehensive analysis conducted in our study, titled "UAV Technology Advancements for Seismic Risk Assessment," emphasizes the transformative influence of cutting-edge technology on seismic risk evaluation and disaster preparedness. This detailed exploration delves into the refined applications of Incremental Dynamic Analysis (IDA) and its profound implications within the context of seismic vulnerability assessment. IDA stands as a fundamental method in our research. This method involves applying incremental seismic pressures, calculating earthquake impacts, and forecasting building structural reactions at various severity levels. Incremental Dynamic Analysis (IDA), which evaluates non-linear behavior, can help comprehend masonry construction performance and degradation. IDA can discover vulnerable components and critical areas in projects by gradually applying seismic loads. In order to conduct detailed seismic risk assessments, vulnerabilities must be identified. This improves understanding of structural faults and failure sites. This knowledge is needed to create seismic retrofitting and strengthening strategies for masonry structures. The IDA also assesses building structural risk by researching structural vulnerability curves. This study quantitatively evaluates performance and seismic severity-based structural damage risk. Quantification helps prioritize mitigation activities and allocate resources. Our research employs IDA and cutting-edge unmanned aerial vehicle technology to improve seismic vulnerability assessment by giving structural insights and forecast accuracy. This method affects disaster preparedness and community resilience in seismically active areas worldwide.

Application of UAV Technology to Seismic Risk Assessment

This remarkable advance illuminates rural brick structures' seismic sensitivity. The combination of unmanned aerial vehicle technology and seismic risk assessment is novel. Unmanned aerial aircraft with high-resolution cameras make taking detailed photos easier. These photographs show important architectural and structural features for seismic risk assessment. This unique method combines UAV oblique imaging with incremental dynamic analysis to improve structural evaluations. Integrating UAV and IDA data greatly improves seismic vulnerability evaluations. This approach ushers in a unique, data-driven methodology, predicting potential damage scenarios for masonry structures during seismic events, bridging the divide between data acquisition and structural analysis. Moreover, the synergy between cutting-edge technology and traditional methodologies is exemplified by the establishment of a unified coordinate system for 3D reconstruction, a foundational step in this method of structural vulnerability assessment. This crucial calibration ensures precise spatial analysis and assumes a central role in refining seismic vulnerability assessments (**Figure 6**).

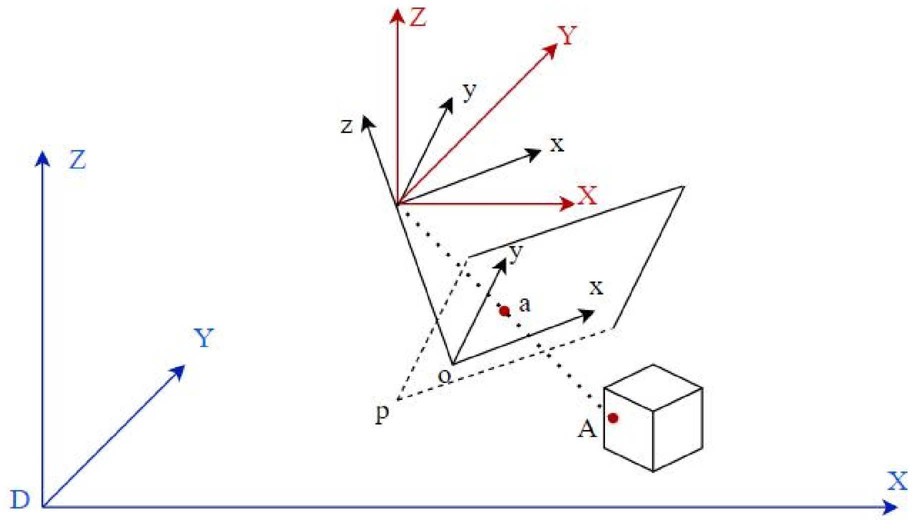

Figure 6. Schematic Diagram of Common Coordinate System (3D Reproduced Diagram)

The process encompassed data acquisition, image data verification, POS data decomposition, and tilt photography-based 3D modeling, resulting in a real 3D model displayed in **Figure 7**. Following ground feature point location and house distance accuracy verification, the UAV photogrammetry-derived 3D model meets reliability and accuracy standards, meeting requirements for subsequent experiments and research purposes.

Figure 7. Schematic of the Real-life 3D Model of the Study Area

The study underscores the immense potential of UAV technology in mitigating seismic risks in rural areas. UAVs expedite data collection, minimize risk to human assessors by eliminating the need for hazardous on-site inspections, and provide comprehensive structural insights. The analysis findings emphasize the vital role of advanced software and modeling tools, in enhancing the understanding of structural vulnerabilities. These tools facilitate the identification of damage indicators and structural weaknesses, complementing visual inspections. In conclusion, the results of this study confirm the pivotal role of UAV technology advancements in seismic risk assessment. The synergistic merging of advanced technology with IDA (Incremental Dynamic Analysis) ushers in a transformative paradigm, poised to fortify seismic preparedness, mitigate damage, and significantly bolster life-saving efforts in regions prone to seismic activity (**Table 2**). This pioneering methodology bears the potential to revolutionize disaster risk management practices and elevate the assessment of critical infrastructure. It stands as a beacon, illuminating the path towards more resilient communities in the daunting presence of seismic threats.

Table 2. Analysis Results for "UAV Technology Advancements for Seismic Risk Assessment"

Theme	Findings and Insights
Data Acquisition	UAV inclined photography technology improves the efficiency of information acquisition.
	Reduced the need for on-site inspections in remote or hazardous locations.
Data Processing	Georeferenced imagery stitched into 3D models for comprehensive analysis.
	Identification of critical damage indicators (cracks, deformations) for improved vulnerability assessment.
Incremental Dynamic Analysis	Integration of UAV-acquired data enhanced seismic damage prediction accuracy.
	More accurate understanding of structural defects and rapid seismic vulnerability assessment.
Overall Contribution	UAV technology advancements offer efficient and precise methods to enhance seismic preparedness and reduce damage in seismic-prone areas.

Structural Vulnerability Analysis of Rural Masonry Buildings

In the entire structural vulnerability evaluation of rural masonry buildings, the key components that form the foundation of seismic risks are investigated. This study made major discoveries that could help understand and reduce these threats. Poor building procedures and low-quality or inadequately reinforced materials cause structural difficulties in many rural brick buildings, according to the study. Given the rising seismic activity in rural China, it is troubling that many of these buildings were not seismically retrofitted. The findings underline the need to address structural vulnerabilities and take steps to prevent damage and preserve lives before, during, and after seismic events.

The finite element program SeismoStruct simulated two-story masonry dwellings in the investigation area. Ten ground shaking records were selected based on Incremental Dynamic Analysis (IDA) to accurately assess seismic activity in structures. **Figure 8** displays the 10 created and concatenated IDA curves for viewing. These IDA curve clusters vividly illustrate the uncertainties in ground shaking and their impact on structural response. Notably, the IDA curves exhibit similar trends at lower Peak Ground Acceleration (PGA) values, but as PGA increases, the dispersion among curves becomes more pronounced. In instances of structural collapse, the maximum peak acceleration of ground shaking ranges from 0.6g to 1.1g, signifying significant differences in structural response to varying seismic effects. This substantial divergence highlights the varied structural responses under distinct seismic influences.

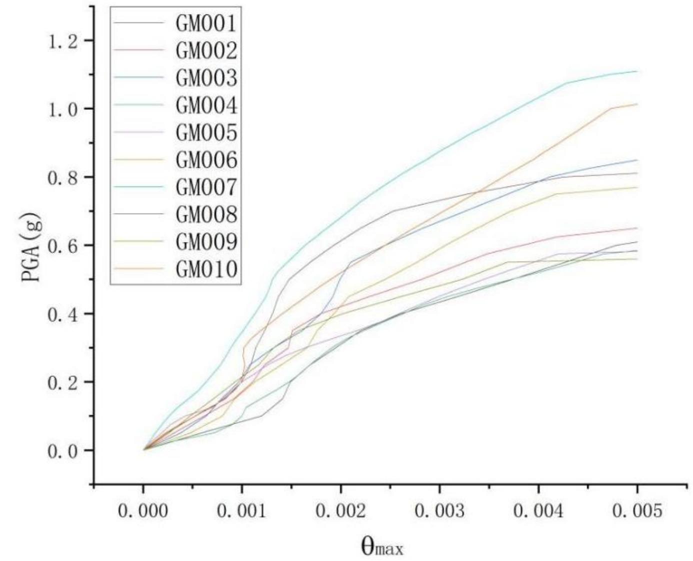

Figure 8. Cluster of 10 IDA Curves under Seismic Action

According to the steps of seismic susceptibility analysis, the probability functions of structural engineering demand parameters and ground shaking parameters are calculated. The logarithm is taken for the ground shaking intensity index (IM: PGA)and structural damage index (DM: $\theta_{\max}$), and a linear regression analysis is performed, and the regression equation is:

$$\ln(\theta_{\max}) = -5.4237 + 0.9157\ln(PGA)$$

According to the above equation, the susceptibility curve is drawn, as shown in **Figure 9**, the horizontal coordinate of the curve is the ground vibration intensity index (PGA), and the vertical coordinate is the probability of exceeding P_f . With the gradual increase of the PGA, the susceptibility curve as a whole shows an S-shape, and the slope is increasing and then decreasing. The structural susceptibility curve can quantify the failure probability of different damage states of the structure under different seismic actions, which provides a reliable basis for seismic damage prediction and seismic risk assessment.

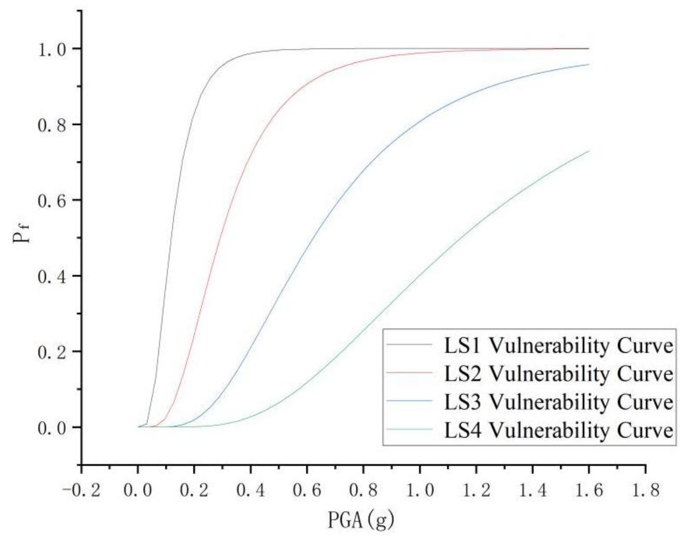

Figure 9. Structural Vulnerability Curve

Reducing dangers requires community education regarding masonry restoration and strengthening. These projects encourage earthquake-resistant buildings with locally produced materials and empower rural populations to make housing decisions. The study also shows cutting-edge technology that can assess rural brick building structural danger. UAV technology and the IDA framework increase damage forecast accuracy and simplify earthquake risk mitigation measures. Using the IDA framework to model a structure's response to various seismic stresses allows for a full examination, vulnerability identification, and improved damage prediction in seismic events. Three-dimensional models produced from photos show a building's structure and vulnerabilities. Precision and thoroughness rise considerably when these advanced techniques are used in review. The analysis shows that rural masonry buildings' structural risk must be addressed holistically. They prioritize community engagement, education, and cutting-edge technologies to reduce earthquake risk (**Table 3**).

Table 3. Analysis Results for "Structural Vulnerability Assessment of Rural Masonry Buildings"

Theme	Findings and Insights
Structural Vulnerability	Many rural masonry structures have poor seismic performance due to substandard construction methods and poor quality materials.
	The lack of seismic retrofitting in these structures poses significant risks in seismic-prone areas.
Community Engagement	Community-based initiatives and awareness programs are vital for raising awareness and facilitating seismic retrofitting.
	Education empowers rural residents to make informed decisions about adopting seismic-resistant construction techniques and materials.
Technological Integration	The integration and innovation of UAV technology with IDA technology provide an efficient means for earthquake damage prediction as well as seismic risk assessment.
Overall Contribution	Addressing structural vulnerabilities, community engagement, and technology integration collectively enhance rural seismic risk mitigation efforts.

Seismic Risk Mitigation in Rural China

Researching earthquake mitigation methods in rural China helps understand the challenges and potential of protecting vulnerable communities. A crucial discovery illuminates rural masonry buildings. Poor construction and a lack of seismically resistant features make these constructions earthquake-prone. The study emphasizes personalized mitigation measures, especially in areas with many of these residential buildings. The report focuses on grassroots community-based projects and activities in rural China. These projects, funded by government programs and international organizations, can raise awareness and train. Through rural engagement, these programs help local communities make informed house upgrade decisions, improving mitigation measure sustainability. White model is an untextured three-dimensional model made from three-dimensional TINs' geographical position data. **Figure 10-a** illustrates the data-generated schematic diagram. Cracks and deformation are detected by this model, making it crucial to the investigation. Texture mapping creates a three-dimensional modeling effect that helps see structural conditions and deterioration, improving vulnerability assessment (**Figure 10-b**).

(a) 3D White Film **(b)** 3D model after Texture Mapping

Figure 10. Comparison of the Effect before and after Texture Mapping

The study suggests using unmanned aerial vehicles (UAVs) for remote sensing and inclination photogrammetry to increase seismic risk reduction in rural China. These technologies can identify dangerous structures and monitor safety actions, improving disaster preparedness and risk mitigation. These tools can accurately assess rural masonry building structural flaws and disseminate data in real time, improving earthquake resilience in rural areas. Finally, the study illuminates rural China's complicated earthquake risk reduction challenges and prospects. Masonry structures, community interaction, and innovative technologies are essential for seismic protection in rural locations. The report emphasises the need for rural community-specific mitigation solutions. It advocates community engagement, education, and technical innovations to improve earthquake preparedness and reduce their destructive impacts.

DISCUSSION

This work improves seismic risk assessment by reviewing the literature and using novel methods. Incremental Dynamic Analysis (IDA) and cutting-edge UAV technologies reduce seismic risk in rural China for masonry projects. This is especially true in China. This method solves long-standing seismic risk assessment difficulties in novel ways. This study proves that masonry projects deteriorate and shows the limitations of field surveys. The accurate and cost-effective technology of unmanned aerial vehicles has made manual data collection obsolete. Unmanned aerial vehicles (UAVs) with high-resolution cameras can speed up data collection while remaining safe, which is especially useful in remote or dangerous places. This technological discovery is transforming seismic risk assessments in China and giving a method that may be scaled up for use elsewhere.

UAV data improves incremental dynamic analysis and seismic vulnerability evaluations. High-resolution imaging collects structural data to better understand each structure's seismic stress sensitivity. Visualizing the structure achieves this. Inspection identifies damage signs including fractures and deformations, improving structural evaluations. A data-driven method using UAVs and computer analysis can improve seismic damage prediction, structural reinforcement, and risk assessment. This method can also increase risk assessment accuracy. Modern software, modeling tools, and technology are working to integrate unmanned aerial vehicles. Brick structure difficulties can be addressed with a full vulnerability study using 3D modeling, structural analysis tools, and UAV data. This examination can fix brick structure issues. Finding faults and deterioration signals in rural masonry projects is easier by simulating seismic reactions. Because simulations are more accurate. Mitigation solutions must consider both physical and structural properties of structures to be effective.

It achieved its main goal and reduced dangers and prepared for seismic disasters. Due to the severity of seismic events, risk evaluations and safeguards are necessary to reduce their impact. Structural analysis and unmanned aerial vehicles can save lives and money. Technological advances may change global earthquake risk assessment and management. The "UAV Technology Advancements for Seismic Risk Assessment" study shows its importance. Computer analysis and modern UAV technology are effective and precise in brick-featured rural areas. This work has major consequences for seismically vulnerable communities' safety and resilience, thus they must be addressed. This work has major repercussions. Since technologically driven innovation is changeable, it's crucial to comprehend its effects.

CONCLUSION

The study "UAV Technology Advancements for Seismic Risk Assessment" showed the benefits of combining novel UAV technology with structural analysis. This investigation emphasized the need for more accurate and effective seismic risk assessments. This is especially important in rural China, where brick houses are common. A complete literature review and data analysis inform this study on the primary influence of a new approach on risk reduction and catastrophe preparation. The findings show how unmanned aerial vehicle technology affects seismic risk assessment. In seismically active areas with brick buildings, this is especially true. High-definition cameras on unmanned aerial vehicles (UAVs) speed up data collection, eliminate field inspections, and improve security, especially in dangerous areas. Additionally, it boosts safety. UAV and IDA data are required to be linked to improve seismic vulnerability evaluations. Since the combo worked best, this was true. This integration simplifies structural problem detection and reveals the earthquake vulnerability of masonry projects. This relationship streamlines structural vulnerability detection. Teamwork combining UAVs, modern software, and modeling tools has enhanced structural fault understanding. This allows for improved risk mitigation measures. The study shows how technology-driven innovation may transform seismic risk assessment and preparedness. In conclusion, this study illuminates technological innovation. Seismically active locations will become safer and more resilient. Because we are pushed toward this future.

THEORETICAL AND PRACTICAL IMPLICATIONS

Modern Unmanned Aerial Vehicle (UAV) technology may reduce vulnerability risk assessment costs and human and economic costs. The study has major implications for community-specific disaster preparedness and risk reduction. Community involvement and education are crucial to earthquake risk reduction. Educating rural populations about earthquake-resistant construction technology focuses grassroots efforts to improve community safety and resilience. Improving disaster preparedness requires raising awareness and helping with seismic retrofitting. Community-based programs are necessary for both goals.

Bridging rural knowledge gaps requires public information on locally produced materials and construction norms suited to community culture and economy. It stresses the necessity of adapting educational resources to a community's needs and proposes that similar places around the world could benefit from seismic activity-reduction education. Advanced technology like UAVs can help analyze structural danger, according to the study. These tools help earthquake-prone areas identify damage indicators and track mitigating activities. Technical advances and traditional structural analysis methods may enhance structural damage forecasting, reducing seismic damage's negative effects on people and economies.

Finally, the discovery has major implications for scientific disaster preparedness and risk reduction. The mix of modern and traditional methods shows how innovation may change seismic risk assessment and management. New technology for more accurate and efficient risk assessments will shape disaster preparedness. The study found that earthquake-prone communities can increase their safety and resilience with technical solutions and innovative methods. Community-based activities and technical breakthroughs improve disaster preparedness and risk reduction globally across multiple geographies, according to the study.

OUTLOOK

In summary, "UAV Technology Advancements for Seismic Risk Assessment" showed how modern UAV technology and structural analysis methods may alter seismic risk assessment. This study addressed the urgent need for faster and more accurate seismic risk assessments. In rural China, where brick buildings are ubiquitous, this is crucial. Based on a thorough literature search and analysis of the data, this study examines how this new technique has revolutionized catastrophe preparedness and risk reduction. The findings demonstrate the importance of unmanned aerial vehicle technology in seismic risk assessment. In seismically active places, masonry structures are more vulnerable. In distant or dangerous areas, high-resolution cameras on unmanned aerial vehicles (UAVs) speed up data collection and reduce field survey time. This improves safety. Integrating UAV and incremental dynamic analysis (IDA) data improved seismic risk assessments' precision and comprehensiveness. This was because the combo worked best. This integration illuminates brick structures' seismic susceptibility and simplifies structural problem identification. Integration helps identify structural flaws. A collaborative effort using UAV technology, current software, and modeling tools improved structural flaw understanding. This opens the door to better risk-reduction methods. This study illuminates the revolutionary potential of technology-driven innovation, which is changing seismic risk assessment and readiness. Finally, this study illuminates technology-driven innovation. Increased safety and resilience are coming to seismically active areas. Because we're being thrown into the future.

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