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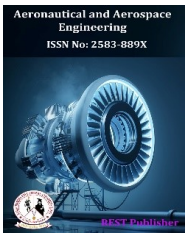

Application of a Focused Ion Beam System to Micro and Nano Engineering Using GRA Method

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ABSTRACT

As our society ages, the prevalence of age-related frailties increases. There is a pressing need for tailored solutions to address these ailments effectively. The demand for tissue engineering is steadily rising, with a particular emphasis on utilizing stem cells to meet this need. Treatments incorporating ultrafast laser-matter interaction processes are becoming increasingly prominent, thanks to their numerous appealing attributes. These include Nano-scale spatial resolution, no thermal characteristics, and the ability to facilitate non-destructive engineering procedures. This review discusses innovative laser-based methods for printing materials suitable for biological applications and for modifying surfaces at the micro- and nanoscale. Simultaneous methods involve solving a series of measurements concurrently, employing various modes, discrete or continuous. On the other hand, information transmission techniques focus on modeling unique scales and injecting reflections at a continuous level within messaging programs Investigating the utilization of Multi-Attribute Decision Making (MADM) methods in facilitating vertical handovers within wireless networks, this study delves into the integration of weighing with Gray Rational Analysis (GRA). It evaluates the effects of these techniques and ultimately aims to enhance the precision of fault diagnosis across the entirety of the power grid. Specifically, it reanalyzes faults within overlapping regions utilizing the GRA methodology. The viability and effectiveness of the approach are assessed through examination of two instances. Concurrently, a combination of gray communication analysis and analytic hierarchy process is employed to construct an assessment framework. This framework adeptly manages uncertainties in water infiltration impact indices, providing a literal representation of the significance of each effect. Based on the analysis of technological advancements within software companies, a study was conducted to identify key traits. Subsequently, an assessment metric for innovation proficiency was devised, focusing on the capacity to introduce and develop novel technologies. This evaluation utilizes both Analytic Hierarchy Process (AHP) and Grey Relational Analysis (GRA) algorithms for estimation purposes. Unique Properties is got the first rank whereas is the Challenges and Opportunities is having the Lowest rank.

1. INTRODUCTION

The cell, akin to various stem cell varieties, exists in both soluble and surface-bound forms within the extracellular environment. It possesses the ability to detect and react to gradients of nearby cues, facilitating cell-to-cell communication through juxtacrine interactions. Additionally, it responds to signals, which are predominantly extracellular in nature. This signaling process is influenced and reciprocated by the extracellular matrix, as well as by the architectural and nanotopographic characteristics of the environment. Cells engage with extracellular matrix (ECM) proteins like fibronectin

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either via signaling domains or direct attachment. This interaction is heightened with the inclusion of growth factorsref1.An ongoing hurdle in the advancement of tissue-engineered constructs lies in the limited availability of replenishable cell sources. This encompasses embryonic, induced pluripotent, and adult stem cells. Stem cells, renowned for their healing and regenerative capabilities, hold significant promise as cell sources in medical applications. Recent innovations in fabrication technology have paved the way for the creation of cells that possess the ability to self-renew and differentiate into various cell types. These cells, capable of replenishing themselves and assuming diverse cellular identities, offer promising potential for tissue regeneration. Through cultivation, damaged, injured, and aged cells can be harvested for this purpose. The advent of precise micro- and nanotips, alongside variable stiffness and substrates with specific chemical compositions, has significantly contributed to this advancement in tissue engineeringref2.In particular, the adhesion and shape of cells can be regulated by manipulating surface chemistry and microengineering techniques. This combination of approaches has been demonstrated to be effective. Surface chemistry plays a crucial role, as does the biological context relevant to medical applications. Additionally, surface topology can be employed to exert influence. Two articles in this journal discuss the manipulation of biological systems, particularly focusing on engineering surface landscapes to control specific features and enhance regeneration. They explore the potential of such techniques in medicinal applications, particularly in stimulating the growth and differentiation of cells for next-generation bioreactors. This comprehension holds significant promise for advancements in engineering endeavorsref3.The potential emergence of dual-scale characteristics, such as microstructures embellished with nanosized attributes, is notably intriguing in various structural modifications, including surface alterations of specific configurations. Various procedures for producing densely packed microarrays involve the laser-based transfer of materials onto substrates, wherein the resultant features can undergo additional refinement through subsequent chemical treatments to enhance surface propertiesref4.This article discusses the fabrication of micro- and nanostructures using focused ion beam (FIB) technology. It evaluates its various applications, focusing on selected examples. In contrast, electron beam lithography, an alternative method, may require up to two days when utilizing metal lift-off techniques. Numerous instances in the literature illustrate the creation of electron-based structures via beam lithographyref5. Understanding the growth mechanism is crucial for analyzing morphology and material properties, particularly in the context of electron microscopy (EM) systems. This understanding is instrumental in achieving desirable traits such as lightweight construction, high specific surface area, and microscopic features that facilitate efficient electron transfer channels. Nanostructures of EM functional materials are particularly advantageous in promoting innovation due to these attributes. Unlike electromagnetic absorbing materials, protective materials derive their effectiveness not only from absorption but also from reflection, emphasizing the importance of both mechanisms ref6.This article aims to explore advancements in optimizing physiological environments through constrained spatiotemporal regulation with regulatory factors. It discusses techniques in reflective 2D surface engineering for translation into 3D in vitro systems. Recent developments in complex micro/nanoscale regulation of cell responses are also covered. The article reviews engineering surfaces for delivering and manipulating cell behaviors, highlighting state-of-the-art technologies used in biomedical devices and providing updates on potential applicationsref7.Nanoscale silsesquioxane particles are commonly synthesized in an acidic solution with ethanol as the primary solvent. Stirring is typically increased to a speed ranging from 600 to 900 rpm when exposed to air. Higher concentrations of ammonia are utilized to accelerate the condensation process. Layered silicates (2D), single- and multi-walled nanotubes (1D), carbon structures (1D), and polyhedral oligomers are among the preferred materials for synthesizing silsesquioxane nanostructuresref8. Drug delivery systems (DDS) involve modifying a drug's formulation to achieve therapeutic effects in animals or humans. These systems are designed to administer the drug in a controlled manner. In the mid-1960s, researchers introduced arterio-venous silicon rubber microstructures to bypass rabbit blood through a shunt, marking an early advancement in DDS. The first commercialized non-invasive DDS emerged in the 1990s with FDA approval. Since then, drug companies have continually pursued advancements to improve therapeutic outcomesref9.This highly efficient nanomachine exhibits behavior dominated by surface effects due to its small size, making it difficult to explain using traditional principles. Atomistic simulations are computationally expensive, often requiring handling of vast numbers of variables over long timescales. To address this, multidimensional computational approaches are suggested to efficiently capture essential atomic detailsref10.Creating nanostructured domains with nanometer precision is crucial for applications such as photonics. Fabrication techniques like etching enable the implementation of both one-dimensional (1D) and two-dimensional (2D) structures, including gratings designed to meet

specific criteriaref11.For nanoscale light manipulation, isolating and controlling optical cavities is essential. This often requires thinner wavelengths and suspended membranes, involving multiple demanding lithographic steps. Materials such as GaAs are widely used in photonics, sensing, and nanoelectronicsref12.Biomimetic approaches enhance wound healing and support regenerative medicine. Techniques such as coatings on medical equipment and biomimetic particles show promise in tumor immunotherapy. This field aims to leverage the body's immune system, particularly T lymphocytes, to target tumor antigens and improve cancer treatment outcomesref13.Investigations into embryonic stem cells (ESCs) and induced pluripotent stem cells (iPSCs) have advanced the understanding of pluripotency. These cells serve as abundant sources for generating multipotent progenitor cells, aiding in tissue engineering and regenerative medicine applicationsref14.Finally, nanoscale characteristics pose challenges for macroscopic simulation models, particularly in MEMS and NEMS systems. To address rapid atomic movements and frequent updates, improved algorithms such as enhanced neighbor list methods are proposed to accelerate simulationsref15.

2. MATERIALS AND METHOD

- Scale: A scale is a tool utilized to gauge a specific item, employed for either establishing or evaluating the positions or quantities within a compilation. For instance, a 5.5 magnitude earthquake on the Richter scale, or zero patient treatments, indicating the top ten rankings.
- Interdisciplinary Nature: Intermediate refers to the combination of two or more educational disciplines. This approach involves merging fields together. In addressing various social issues, which are complex and multifaceted, relying on a single perspective or solution isn't feasible. Hence, tackling these problems requires interdisciplinary collaboration and communication among different departments or areas of expertise.
- Novel Manufacturing Techniques: Three broad types of manufacturing processes include Make to Stock (MDS), Make to Order (MTO), and Make to Assemble (MTA). These strategies encompass factors such as labor costs, inventory management, overhead expenses, customization, and speed of production and order fulfillment. Each approach carries its own set of pros and cons in terms of efficiency, responsiveness to customer demands, and overall operational effectiveness.
- Unique Properties: Fannie Mae considers even 3D printed houses to be unique as long as they follow traditional construction methods, unlike those utilizing unconventional designs and materials. Unique properties are typically uncommon in most areas.
- Challenges and Opportunities: Facing challenges, whether they are personal or professional, presents opportunities for growth and development. To enhance one's ability to tackle such challenges, focusing on learning and skill development is crucial. A platform dedicated to providing challenges for learning could serve as an excellent resource. Confronting difficulties often necessitates acquiring new skills and knowledge, thereby fostering personal and professional development.
- Technological Advancement: Many users remain unconvinced by this term, particularly in the realm of technology. Such technology is often viewed as unsustainable or not yet mainstream. Despite this, it holds promising potential for the future and can offer significant value across various industries or scientific fields.
- Interdisciplinary Collaboration: Bringing together various viewpoints, approaches, theories, and information within a specific domain can lead to the emergence of innovative concepts, understandings, and resolutions through collaborative efforts across disciplines.
- Social and Environmental Implications: The environmental and social impacts directly concern your operations. These activities are intertwined with the natural environment and consequently influence people, leading to both positive and negative effects. These effects manifest in various ways, such as biodiversity loss, climate change, water quality degradation, impacts on human health, infringement of human rights, and adherence to labor standards. These implications extend beyond mere business concerns, affecting social development and more broadly impacting

communities and society at large.

- Ethical Considerations: Respecting the dignity and rights of research participants, as well as adhering to ethical principles to safeguard their interests, is crucial. Given the involvement of humans in research, it is imperative that all studies undergo thorough review by an ethics committee.

3. GRA METHOD

The discussion revolves around the utilization of Vertical Handover (VHO) in wireless networks, particularly in the context of its application in the background. The integration of GRA (Grey Relational Analysis) and AHP (Analytic Hierarchy Process) as a weighting technique in VHO is highlighted as a method that offers efficiency in executing handovers. This study explores the optimization of attribute weighting using GRA Multi-Attribute Decision Making (MADM) for different types of user traffic. A thorough performance evaluation of various combinations is conducted through comprehensive analysis [16]. The objective is to enhance the performance of the GA-CPSO optimization algorithm combined with PNN, specifically in the context of power grid fault detection accuracy. This improvement is targeted towards critical applications within the power grid fault detection scenario. The proposed approach focuses on refining PNN and GRA to effectively detect and segment faults in power grids. Fault diagnosis in power grids using Artificial Neural Networks (ANN) can be categorized into two main types: centralized fault detection and distributed fault detection. In the context of smaller power grid setups, centralized fault detection is deemed appropriate. However, with the evolving complexity of modern power grids, centralized fault diagnosis methods fall short of meeting the necessary diagnostic requirements [17]. The clarity of the connection among symbols is evident. However, there exists a gray area in communication where Analysis (GRA) and Analytical Hierarchy Process (AHP) serve as a pioneering assessment framework. These methods are implemented within GRA to rank codes, transitioning water from an index to address ambiguity, and are additionally employed in categorizing intrusion risks [18]. Technological advancement is crucial for industrial enterprises and plays a pivotal role in their development. Software innovation, particularly in the realm of technology, is indispensable for companies. It enhances cost-effectiveness in investments and fosters the effective development of technological innovation capabilities, which are essential for growth. Over the past ten years, the expansion of high-tech sectors has emerged as a primary catalyst for economic advancement. Within this realm, the software industry stands out as a particularly rapid-growing segment, exerting a progressively significant influence on the domestic economy [19]. The efficiency of the optimization technique reveals outcomes that signify the character. Utilizing a combination of RSM-based Box-Meyer design and GRA, the rough grinding process parameters were enhanced to indicate success. An empirical relationship was established through successful GRG of process parameters for prediction, particularly showing advancements in hard grinding performance when employing RSM with GRA [20]. The process parameters, including the rotation speed of the mounting and the incorporation of Silicon Carbide Micro powder (SiC), were examined in relation to their impact on a hypoeutectic AlSi alloy. This alloy was employed in the experimentation involving hollow cylindrical work pieces. The study utilized the Response Surface Methodology (RSM) to enhance quality outcomes and was conducted through a comprehensive full factorial design approach. As the weight and velocity of sliding escalate, the wear rate of the composites also rises. Conversely, as the load and sliding speed increase, the friction coefficient of the composite diminishes. Hence, the centrifugal casting method is opted for sample production due to these considerations [21]. This study introduces a unique method for evaluating fatigue crack conditions in a 2K-H planetary gear set through Gray Correlation Analysis (GRA). It involves simulating signals and applying GRA to select features and weigh them algorithmically to estimate damage scales. The paper also presents a dynamic response rating system, which integrates an analytical model for statistically analyzing damage feature information. Validation of the proposed approach is conducted using data from damage seed tests [22]. The RUM utilizes a diamond-reinforced rotary core drill that simultaneously vibrates via ultrasonic waves while remaining static. This process aids in the precise feeding of the drill into the work piece at a controlled feed rate. Continuous provision of a set volume of coolant within the drill core serves multiple purposes: it effectively clears away sward, preventing tool jamming, and ensures cooling of the machine zone. The rotational grinding of the tool and the abrasive effects induced by the ultrasonic movement synergistically micro-form the material, resulting in the separation of chips [23]. A general concept or particular

hypotheses can be broken down into smaller hypotheses within a theory and can be represented visually. This allows for a clearer understanding of the scope of a single study, whether it's exploring a broad concept with inherent limitations or examining a crucial aspect of the theory. Likewise, in statistical meta-analysis, a Hierarchy of Hypotheses (HoH) can effectively structure diverse literature, even when it's highly varied [24]. Gray system theory encompasses five primary areas: gray prediction, gray correlative analysis (GRA), gray modeling, gray programming, and gray control. GRA, a crucial component of this theory, operates within organizational contexts, leveraging its multifactorial approach to address complex interactions among variables, making it ideal for problem-solving tasks. Due to its adaptability to unique datasets and its ability to handle incomplete information effectively, GRA finds widespread application in resolving uncertain problems across various domains [25]. The GRA-Fuzzy logic model stands out as a pivotal tool for analyzing shape elements derived from numerical data. It plays a crucial role in determining product shape design attributes and their correlation with related product design samples, often accompanied by visual representations. In this context, both system users and designers are equally indispensable for its effective operation. Thus, this article introduces a novel approach utilizing GRA-Fuzzy logic to scrutinize the interplay between product shape elements and specific product images [26]. Rapid differentiation among plant species is essential in nursery plant production. Ensuring the greatest variety of products involves implementing new control systems in the production process and preventing mixing of varieties during shipping to maintain cleanliness standards. Presently, DNA analysis and various identification techniques are extensively utilized for this purpose [27]. Modern portfolio theory (MPT) focuses on estimating expected returns in the market relative to risk. It emphasizes constructing portfolios aimed at growth while catering to risk-averse investors. MPT highlights the relationship between risk and expected return, advocating for strategies that aim to minimize risk while maximizing returns. In situations of uncertainty, the Pythagorean approach tends to be nuanced and adaptable. Within the context of the Multi-Attribute in Relational Analysis (GRA) framework, employing the Group Decision Making (MAGDM) method is akin to conducting research such as portfolio selection. Unlike preset tasks, the GRA technique proves valuable as it allows for the determination of criteria weights through open-ended and linear programming methods. Evaluation is achieved through model creation rather than through assigned tasks [28]. Analysis of Variance (ANOVA) and Gray Relational Analysis (GRA) were utilized to identify influential parameters. The study revealed correlations between micro hardness and compressive strength, leading to the development of regression models for both. It was observed that increasing the amount of zirconia added to the alumina matrix enhanced compressive strength but decreased hardness. Additionally, Response Surface Methodology (RSM) was employed, alongside GRA, to optimize multiple responses, aiming for improved hardness and compressibility, ultimately achieving robustness in the process [29]. The aim of this research is to explore various common fuzzy numbers through the lens of a novel GRA (Grey Relational Analysis) method for decision-making criteria. In this extended version, we introduce Dombi norms and the Bonferroni averaging operator concept. We address ambiguity in certain numbers by considering their reliability. Our approach involves the development of functional laws and continuous integration operators, alongside establishing fundamental properties. Additionally, we delve into discussions regarding boredom, boundary, and communication aspects within the context of our study [30].

4. ANALYSIS AND DISCUSSION

TABLE 1. Micro and Nano Engineering

	Technological Advancement	Interdisciplinary Collaboration	Social and Environmental Implications	Ethical Considerations
Scale	80.23	110.23	81.61	80.26
Interdisciplinary Nature	15.13	111.15	51.41	40.36
Novel Manufacturing Techniques	16.26	170.20	31.21	50.96
Unique Properties	59.23	158.45	11.51	84.19
Challenges and Opportunities	45.15	116.89	71.91	50.16

Table 1 shows the Micro and Nano Engineering for Grey relational analysis. Scale, Interdisciplinary Nature, Novel Manufacturing Techniques, Unique Properties, Challenges and Opportunities. Technological Advancement, Interdisciplinary Collaboration, Social and Environmental Implications and Ethical Considerations Evaluation value.

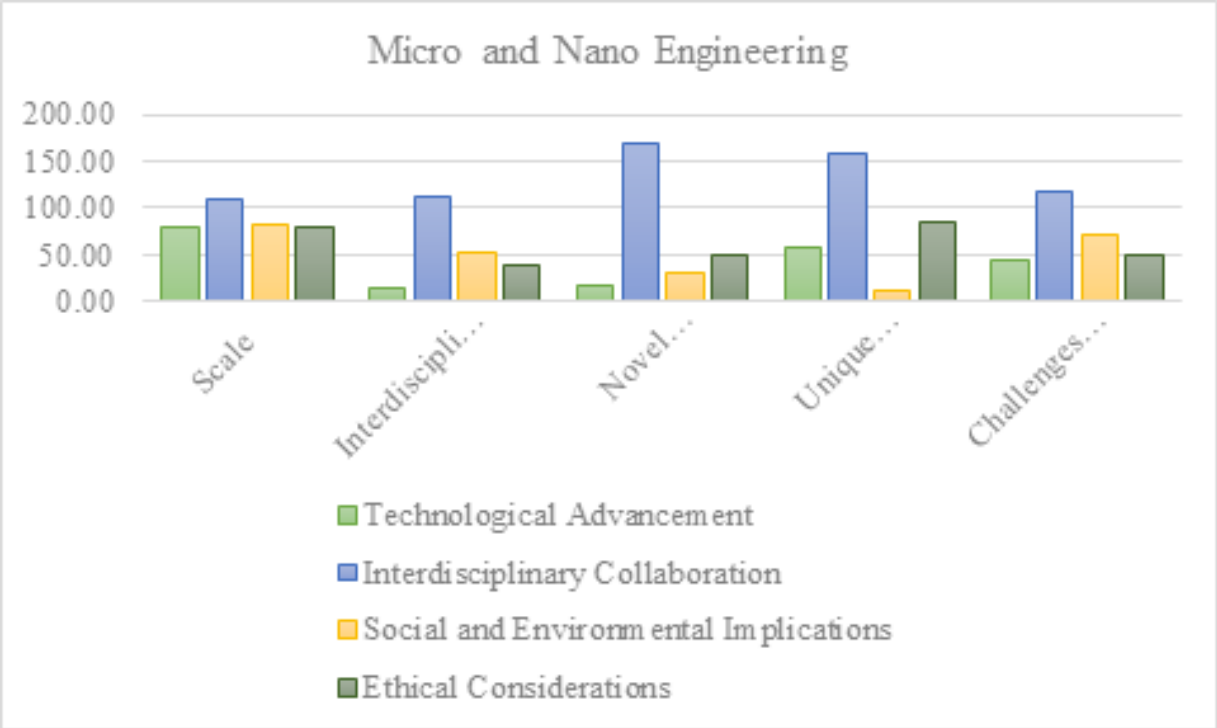

FIGURE 1. Micro and Nano Engineering

Figure 1 shows the Micro and Nano Engineering for Grey relational analysis. Scale, Interdisciplinary Nature, Novel Manufacturing Techniques, Unique Properties, Challenges and Opportunities. Technological Advancement, Interdisciplinary Collaboration, Social and Environmental Implications and Ethical Considerations Evaluation value. From the figure 1 and table 1 it is seen that Scale is showing the Highest Value for Technological Advancement and Interdisciplinary Nature is showing the Lower value. Novel Manufacturing Techniques is showing the Highest Value for Interdisciplinary Collaboration and Scale is showing the Lower value. Scale is showing the Highest Value for Social and Environmental Implications and Unique Properties is showing the Lower value. Unique Properties is showing the Highest Value for Ethical Considerations and Interdisciplinary Nature is showing the Lower value.

TABLE 2. Normalized Data

	Technological Advancement	**Interdisciplinary Collaboration**	**Social & Env. Implications**	**Ethical Considerations**
Scale	1.0000	0.0000	0.0000	0.0897
Interdisciplinary Nature	0.0000	0.0153	0.4308	1.0000
Novel Manufacturing Techniques	0.0174	1.0000	0.7190	0.7582
Unique Properties	0.6774	0.8041	1.0000	0.0000
Challenges and Opportunities	0.4611	0.1111	0.1384	0.7764

Table 2 shows the Normalized data for Micro and Nano Engineering. Scale, Interdisciplinary Nature, Novel Manufacturing Techniques, Unique Properties, Challenges and Opportunities. Technological Advancement, Interdisciplinary Collaboration, Social and Environmental Implications and Ethical Considerations it is also the Normalized value.

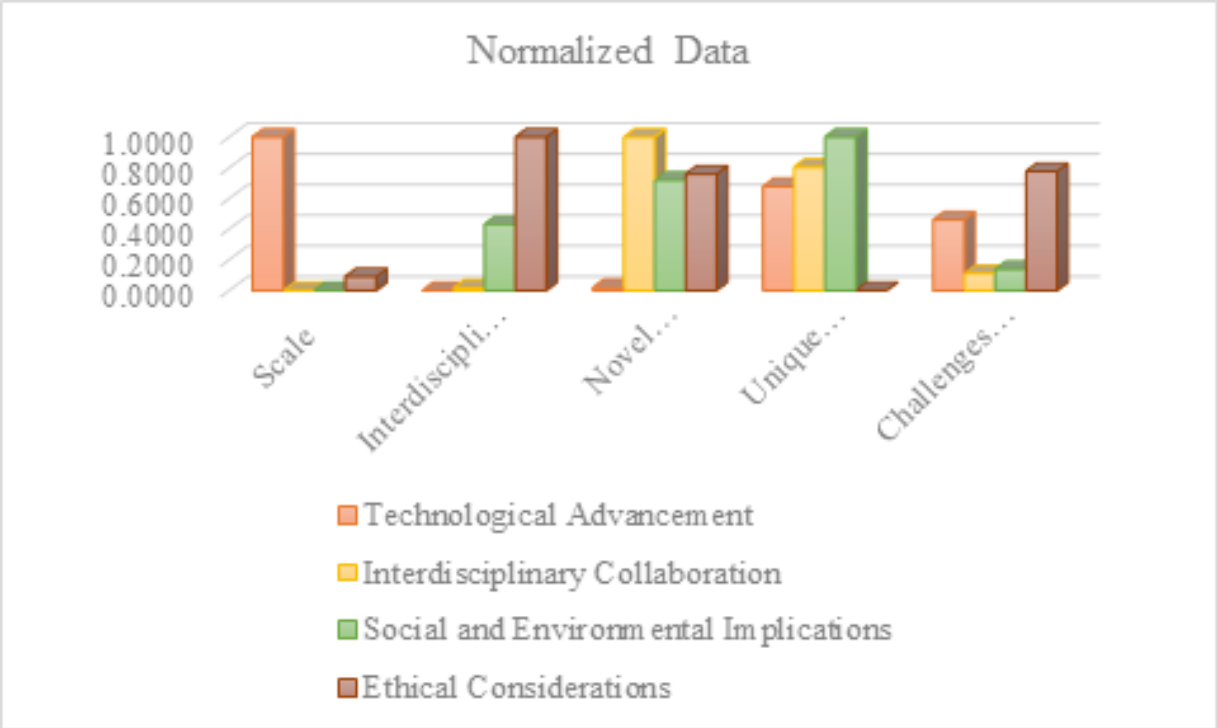

FIGURE 2. Normalized data

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TABLE 3. Deviation Sequence

	Technological Advancement	**Interdisciplinary Collaboration**	**Social & Env. Implications**	**Ethical Considerations**
Scale	0.0000	1.0000	1.0000	0.9103
Interdisciplinary Nature	1.0000	0.9847	0.5692	0.0000
Novel Manufacturing Techniques	0.9826	0.0000	0.2810	0.2418
Unique Properties	0.3226	0.1959	0.0000	1.0000
Challenges and Opportunities	0.5389	0.8889	0.8616	0.2236

Table 3 shows the Deviation sequence for Micro and Nano Engineering. Scale, Interdisciplinary Nature, Novel Manufacturing Techniques, Unique Properties, Challenges and Opportunities. Technological Advancement, Interdisciplinary Collaboration, Social and Environmental Implications and Ethical Considerations it is also the Maximum or Deviation sequence value.

TABLE 4. Grey Relation Coefficient

	Technological Advancement	**Interdisciplinary Collaboration**	**Social & Env. Implications**	**Ethical Considerations**
Scale	1.0000	0.3333	0.3333	0.3545
Interdisciplinary Nature	0.3333	0.3368	0.4676	1.0000
Novel Manufacturing Techniques	0.3372	1.0000	0.6402	0.6740
Unique Properties	0.6078	0.7185	1.0000	0.3333
Challenges and Opportunities	0.4813	0.3600	0.3672	0.6910

Table 4 shows the Grey relation coefficient for Micro and Nano Engineering. Scale, Interdisciplinary Nature, Novel Manufacturing Techniques, Unique Properties, Challenges and Opportunities. Technological Advancement, Interdisciplinary Collaboration, Social and Environmental Implications and Ethical Considerations it is also Calculated the Maximum and minimum Value.

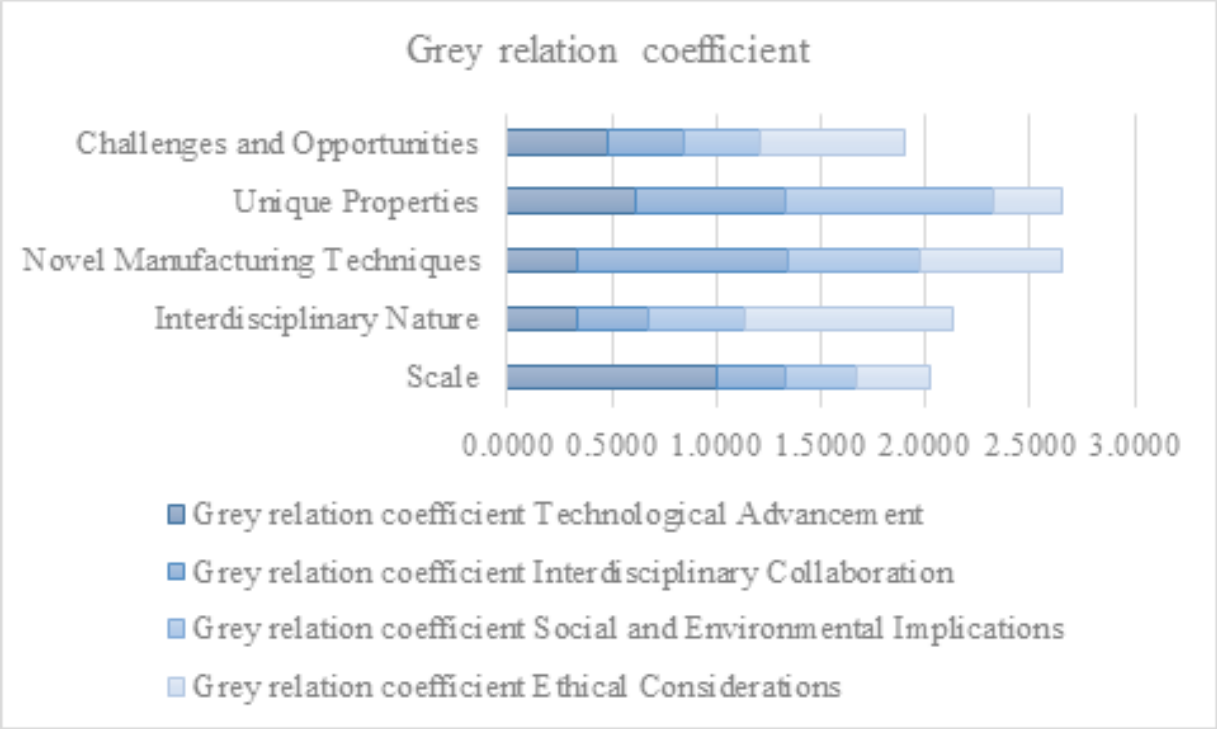

FIGURE 3. Grey relation coefficient

Figure 3 shows the Grey relation coefficient for Micro and Nano Engineering. Scale, Interdisciplinary Nature, Novel Manufacturing Techniques, Unique Properties, Challenges and Opportunities. Technological Advancement, Interdisciplinary Collaboration, Social and Environmental Implications and Ethical Considerations it is also Calculated the Maximum and minimum Value.

TABLE 5. Result of Final GRG Rank

	GRG	Rank
Scale	0.5053	4
Interdisciplinary Nature	0.5344	3
Novel Manufacturing Techniques	0.6629	2
Unique Properties	0.6649	1
Challenges and Opportunities	0.4749	5

Table 5 shows the Result of final GRG Rank of GRA for Micro and Nano Engineering. GRG Rank Unique Properties is showing the highest value for GRG Rank and Challenges and Opportunities is showing the lowest value.

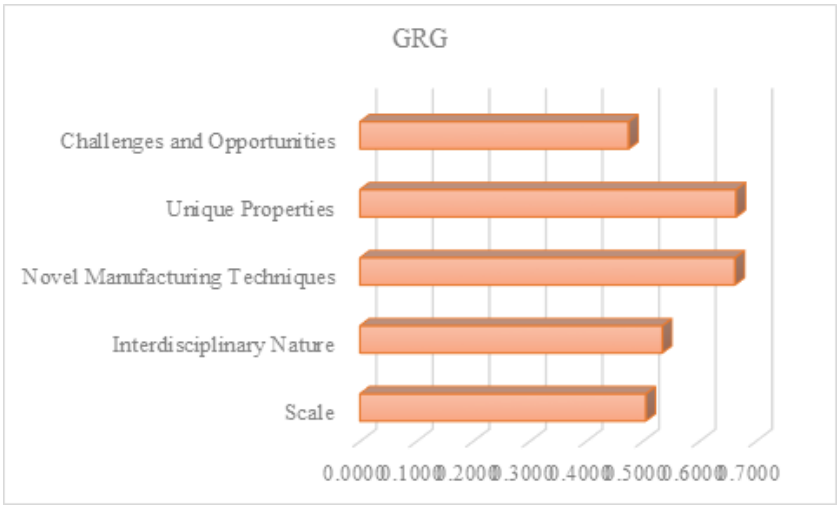

FIGURE 4. GRG

Figure 4 shows the Result of final GRG Rank of GRA for Micro and Nano Engineering. GRG Rank Unique Properties is showing the highest value for GRG Rank and Challenges and Opportunities is showing the lowest value.

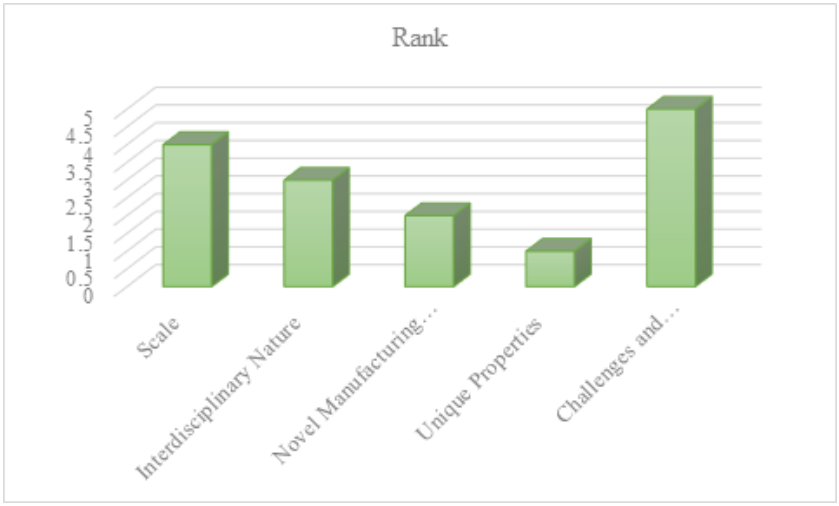

FIGURE 5. Shown the Rank

Figure 5 shows the Rank of GRA for Micro and Nano Engineering. Unique Properties is got the first rank whereas is the Challenges and Opportunities is having the Lowest rank.

5. CONCLUSION

This signaling process is influenced and reciprocated by the extracellular matrix, as well as by the architectural and Nano topographic characteristics of the environment. Cells engage with extracellular matrix (ECM) proteins like fibronectin either via signaling domains or direct attachment. This interaction is heightened with the inclusion of growth factors. Recent innovations in fabrication technology have paved the way for the creation of cells that possess the ability to self-renew and differentiate into various cell types. These cells, capable of replenishing themselves and assuming diverse cellular identities, offer promising potential for tissue regeneration. They explore the potential of such techniques in medicinal applications, particularly in stimulating the growth and differentiation of cells for next-generation bioreactors. This comprehension holds significant promise for advancements in engineering endeavors. Various procedures for producing densely packed microarrays involve the laser-based transfer of materials onto substrates, wherein the resultant features can undergo additional refinement through subsequent chemical treatments to enhance surface properties. This understanding

is instrumental in achieving desirable traits such as lightweight construction, high specific surface area, and microscopic features that facilitate efficient electron transfer channels. Nanostructures of EM functional materials are particularly advantageous in promoting innovation due to these attributes. Unlike electromagnetic (EM) absorbing materials, protective materials derive their effectiveness not only from absorption but also from reflection, emphasizing the importance of both mechanisms. The study focuses on the rapid movement of atoms and the challenges it poses, particularly in terms of frequent updates. To address this, the authors propose an enhanced neighbor list algorithm, which involves instant updates of cell-linked lists to accelerate the construction of adjacency lists. The integration of GRA (Grey Relational Analysis) and AHP (Analytic Hierarchy Process) as a weighting technique in VHO is highlighted as a method that offers efficiency in executing handovers. This study explores the optimization of attribute weighting using GRA Multi-Attribute Decision Making (MADM) for different types of user traffic. However, there exists a gray area in communication where Analysis (GRA) and Analytical Hierarchy Process (AHP) serve as a pioneering assessment framework. The GRA-Fuzzy logic model stands out as a pivotal tool for analyzing shape elements derived from numerical data. It plays a crucial role in determining product shape design attributes and their correlation with related product design samples, often accompanied by visual representations. In situations of uncertainty, the Pythagorean approach tends to be nuanced and adaptable. Within the context of the Multi-Attribute in Relational Analysis (GRA) framework, employing the Group Decision Making (MAGDM) method is akin to conducting research such as portfolio selection. Unlike preset tasks, the GRA technique proves valuable as it allows for the determination of criteria weights through open-ended and linear programming methods. Additionally, Response Surface Methodology (RSM) was employed, alongside GRA, to optimize multiple responses, aiming for improved hardness and compressibility, ultimately achieving robustness in the process [29]. The aim of this research is to explore various common fuzzy numbers through the lens of a novel GRA (Grey Relational Analysis) method for decision-making criteria.

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