

Wireless sensor networks with modular metric spaces

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Abstract

Chistyakov introduced notions of Metric Modular Spaces (MMS) recently. There are motivating chances when integrating the Fixed-Point Theorem (FPT) of MMS into the model and function of a Wireless Sensor Network (WSN), particularly when it comes to reformation network functions, routing algorithms, and data aggregation methods. In WSN data communication, security is a dynamic problem. Dynamic routing algorithms improve data security without requiring any added information by finding the shortest path for data transmission between two connected data packets. Applications requiring remote environmental condition monitoring are increasingly using WSN. Specifically, dense WSNs are evolving as a critical detecting stage for the Internet of Things (IoT). WSN can form the raw data, and to assure effective data transfer, a network model and effective node direction are required. Data aggregation is a method used by WSN to design a data fusion policy, and minimum data is transmitted inside the network. The study's objective is the existence and uniqueness of FPT in MMS via integral type contraction. Also, the iteration of Fixed Points (FP) of Contracts in Settings in MMS was studied in this paper.

Subject Classification: 47H10, 54H25.

Keywords: WSN, Data security, MMS, FPT, ITC, Sensor nodes.

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1. Introduction and Preliminaries

A sensor is any device that links the digital and physical worlds [1]. Wireless Sensor Networks (WSN) are spatial networks of radio-frequency-communicating sensors designed to identify events and send the collected data to a sink located within a specific area. WSNs are epitomized by sensors with constrained computational and power capacities. Fixed Point Theorem (FPT) has several real-time applications in the natural sciences, engineering, and other mathematical theories and is one of dynamic analysis's most practical and valuable subfields. The Banach Contraction Mapping Principle (BCMP), Actually [2], is the most common result of metric FPT. This concept is used in multiple domains, such as integral equations, equations involving differentials, functional problems, and economics.

Modular Metric Spaces (MMS) are principles developed initially by Chistyakov [3-4]. To configure MMS, users must present a poorly integrated converge with a non-metrizable topology. Metric and conventional modular linear spaces are all versions of MMS that resemble Lebesgue, Riesz, and Orlicz spaces of integrated functions. Nakano is the originator of all of these spaces. To get a detailed review of MMS, refer to [5]. An FPT was developed by [6] to address the intent of contractive maps in MMS. The paper presents an integral BCMP and detects FPT for integral-type contractive mappings in MMS that aired FPT for contraction and Kannan-type contraction mappings [7]. Branciari's results were active by others who studied to get Fixed Point (FP) and similar FPT for multiple integral contractive environments on discrete spaces [8-11]. This contribution investigates the uniqueness and presence of FPT in MMS via Integral type contractions. This work can now recall a few well-known definitions and findings from the literature supporting empirical results [12-15].

Proof 1: $z(0, \infty) \times X \times X = [0, \infty] \rightarrow X$ with below conditions

- $a = b$ iff $z_\lambda(a, b) = 0 \because \lambda > 0$
- $z_\lambda(a, b) = z_\lambda(b, a) \because \lambda > 0$
- $z_{\lambda+\mu}(a, c) \leq z_\lambda(a, b) + w_\mu(b, c)$ for all $\lambda > 0 \because a, b, c \in X$

If $(z) \rightarrow (z_\lambda(a, a) = 0 \because \lambda > 0)$ Then
 $w =$ pseudo-modular on ' X '.

Proof 2: $X = \text{set}$. Then

$$z_\lambda^0(a, b) = \begin{cases} \infty & a \neq b \\ 0 & a = b \end{cases}$$

Proof 3: (X, d) be MMS with metric ' d ' and at least 2 points. The indexed objects ' z ' are examples of MMSC on a set X .

- (1) $z_\lambda^1 = d(x, y)$
- (2) $z_\lambda^2 = \frac{d(x, y)}{\phi(\lambda)}$, where $\phi: (0, \infty) \rightarrow (0, \infty)$ is a constant function.

$$(3) \quad z_\lambda^3(x, y) = \begin{cases} \infty & p(x, y) \geq \lambda \\ 0 & p(x, y) < \lambda \end{cases}$$

$$(4) \quad z_\lambda^4(x, y) = \begin{cases} 0 & p(x, y) \leq \lambda \\ \infty & p(x, y) > \lambda \end{cases}$$

Proof 4: 'z' is virtual modules on X and ($a0 \in X$)

$$Xz = Xza0 = \{x \in X : z_\lambda a, a0 \rightarrow 0 \text{ as } \lambda \rightarrow \infty\}$$

$X_z^* = X_z^*(a_0) = \{x \in X : \exists \lambda = \lambda(x) > 0, \text{ then } z_\lambda(a, a_0) < \infty\}$ are MMS (close to a_0)

Proof 5: X_z and X_z^* by MMS.

The order $\{a_n\}$ in X_z (or X_z^*) is 'w' association to $a \in X \leftrightarrow z_\lambda(a_n, a) \rightarrow 0$ as $n \rightarrow \infty$ Else ($\lambda > 0$). Then a is the boundary of $\{a_n\}$.

The order $\{a_n\}$ in X_z is w-Cauchy Order (CO) if $z_\lambda(a_n, a_m) \rightarrow 0$ as $m, n \rightarrow \infty$ Else $\lambda > 0$.

A sub-set M of X_z (or) $X_z^* \rightarrow w$ or $\forall$ any 'w' CO in M is an 'w' true order, and 'z' limits are in 'l'

Proof 6: 'w' be a MMS on X .

A graph $(T: X_z^* \rightarrow X_z^*)$ is a new type 'z', if there exists ($0 < k < 1$) & (λ_0) conditional on 'k',

$$z_{k\lambda}(Tx_1, Tx_2) \leq \Theta_1 z_\lambda(x_1, x_2) + \Theta_2 z_\lambda(x_1, Tx_1) + \Theta_3 z_\lambda(x_2, Tx_2) + \Theta_4 z_\lambda(x_1, Tx_1) + \Theta_5 z_\lambda(x_2, Tx_1) + \Theta_6 [z_\lambda(x_2, Tx_1) + z_\lambda(x_1, Tx_2)] \quad (1)$$

For all $0 < \lambda < \lambda_0, x_1, x_2 \in X_z^*$ and $\Theta_1 + \Theta_2 + \Theta_3 + 2\Theta_4 + \Theta_5 + 2\Theta_6 < 1$.

Proof 7: $T: X_z^* \rightarrow X_z^*$ and $\zeta: [0, \infty) \rightarrow [0, \infty)$ be Lebesgue-Integrable Mapping (LIM), if there exists $\Theta \in [0, 1)$ such that $\forall x_1, x_2 \in X_z^*$

$$\int_0^{d(Tx_1, Tx_2)} \zeta(t) dt \leq \Theta \int_0^{d(x_1, x_2)} \zeta(t) dt \quad (2)$$

2. Preliminary Results

Proof 1: $X \rightarrow \neq \emptyset$, 'w' $\rightarrow$ MMS on X and $T: X_z^* \rightarrow X_z^*$ is defined as follows

$$z_{k\lambda}(Tx_1, Tx_2) \leq \Theta_1 z_\lambda(x_1, x_2) + \dots + \Theta_6 [z_\lambda(x_2, Tx_1) + z_\lambda(x_1, Tx_2)] \quad (3)$$

For every $\lambda > 0$, $\exists$ an $a_0 \in X_z^* \rightarrow z_\lambda(a_0, Ta_0) < \infty$ and $\zeta: [0, \infty) \rightarrow [0, \infty)$ be LIM such that the mapping T has an FP in X_z^* ; and FP of T is unique.

Proof 2: $a_0 \in X$ and $\{x_n\}_{n=1}^\infty$ is s order in X defined as $x_n = Tx_{n-1} = T^n x_0$, $n = 1, 2, 3, \dots$

$$\int_0^{w_\lambda(x_n, x_{n+1})} \zeta(t) dt = \int_0^{z_\lambda(Tx_{n-1}, Tx_n)} \zeta(t) dt \quad (4)$$

$$\leq \Theta_1 \int_0^{z_\lambda(x_{n-1}, x_n)} \zeta(t) dt + \dots + \Theta_6 \int_0^{[z_\lambda(x_n, Tx_{n-1}) + z_\lambda(a_{n-1}, Tx_n)]} \zeta(t) dt \quad (5)$$

$$\leq \Theta_1 \int_0^{z_\lambda(x_{n-1}, x_n)} \zeta(t) dt + \dots + \Theta_6 \int_0^{[z_\lambda(x_n, x_n) + z_\lambda(x_{n-1}, x_{n+1})]} \zeta(t) dt \quad (6)$$

$$\leq \Theta_1 \int_0^{z_\lambda(x_{n-1}, x_n)} \zeta(t) dt + \dots + \Theta_6 \int_0^{z_\mu(x_n, x_{n+1})} \zeta(t) dt \quad (7)$$

$$\leq \Theta_1 \int_0^{z_\lambda(x_{n-1}, x_n)} \zeta(t) dt + \dots + \Theta_6 \int_0^{z_\lambda(x_n, x_{n+1})} \zeta(t) dt \quad (8)$$

$$(1 - \Theta_3 - \Theta_4 - \Theta_6) \int_0^{z_\lambda(x_n, x_{n+1})} \zeta(t) dt$$

$$\leq (\Theta_1 + \Theta_2 + \Theta_4 + \Theta_6) \int_0^{z_\lambda(x_{n-1}, x_n)} \zeta(t) dt \quad (9)$$

$$\int_0^{z_\lambda(x_n, x_{n+1})} \zeta(t) dt \leq \frac{\Theta_1 + \Theta_2 + \Theta_4 + \Theta_6}{1 - \Theta_3 - \Theta_4 - \Theta_6} \int_0^{z_\lambda(x_{n-1}, x_n)} \zeta(t) dt \quad (10)$$

$$\int_0^{z_\lambda(x_n, x_{n+1})} \zeta(t) dt \leq \Delta \int_0^{z_\lambda(x_{n-1}, x_n)} \zeta(t) dt \quad (11)$$

$$\text{where } \Delta = \frac{\alpha_1 + \alpha_2 + \alpha_4 + \alpha_6}{1 - \alpha_3 - \alpha_4 - \alpha_6}$$

$$\int_0^{z_\lambda(x_n, x_{n+1})} \zeta(t) dt \leq \Delta \int_0^{z_\lambda(x_{n-1}, x_n)} \zeta(t) dt \quad (12)$$

$$\leq \Delta^2 \int_0^{z_\lambda(x_{n-2}, x_{n-1})} \zeta(t) dt \quad (13)$$

$$\text{And Find,} \quad \leq \Delta^n \int_0^{w_\lambda(x_0, x_1)} \zeta(t) dt \quad (14)$$

Now find that $\{x_n\}_{n=1}^\infty$ is a CO in 'X'.

$m, n > 0$ with $m > n$

$$\int_0^{z_\lambda(x_n, x_m)} \zeta(t) dt \leq \int_0^{z_\lambda(x_n, x_{n+1})} \zeta(t) dt + \dots \quad (15)$$

$$\leq \Delta^n \int_0^{z_\lambda(x_1, x_0)} \zeta(t) dt + \Delta^{n+1} \int_0^{z_\lambda(x_1, x_0)} \zeta(t) dt + \dots + \Delta^{n+m-1} \int_0^{z_\lambda(x_1, x_0)} \zeta(t) dt \quad (16)$$

$$\leq \Delta^n \int_0^{z_\lambda(x_1, x_0)} \zeta(t) dt$$

$$m, n \rightarrow \infty$$

$$\lim_{n \rightarrow \infty} z_\lambda(x_n, x_m) = 0 \quad (18)$$

$$\{x_n\}_{n=1}^\infty \text{ is a CO in 'X'}$$

$\{x_n\}_{n=1}^\infty$ is a CO $\{x_n\}$ combine to $a^* \in X$

Proved, x^* is the unique FP of T .

$$\int_0^{z_\lambda(x^*, T x^*)} \zeta(t) dt \leq \int_0^{z_\lambda(x^*, x_{n+1})} \zeta(t) dt + \int_0^{z_\lambda(x_{n+1}, T x^*)} \zeta(t) dt \quad (19)$$

$$\leq \int_0^{z_\lambda(x^*, x_{n+1})} \zeta(t) dt + \int_0^{z_\lambda(T x_n, T x^*)} \zeta(t) dt \quad (20)$$

$$\leq \int_0^{z_\lambda(x^*, x_{n+1})} \zeta(t) dt + \dots + \Theta_6 \int_0^{[z_\lambda(x^*, T x_n) + z_\lambda(x_n, T x^*)]} \zeta(t) dt \quad (21)$$

$$\leq \int_0^{z_\lambda(x^*, a_{n+1})} \zeta(t) dt + \Theta_1 \int_0^{z_\lambda(x_n, x^*)} \zeta(t) dt + \dots \Theta_5 \int_0^{z_\lambda(x^*, x_{n-1})} \zeta(t) dt$$

$$+ \Theta_6 \int_0^{z_\lambda(x^*, x_{n-1})} \zeta(t) dt + \Theta_6 \int_0^{z_\lambda(x_n, x^*)} \zeta(t) dt + \Theta_6 \int_0^{z_\lambda(x^*, T x^*)} \zeta(t) dt \quad (23)$$

$$(1 - \Theta_3 - \Theta_4 - \Theta_6) \int_0^{z_\lambda(x^*, T x^*)} \zeta(t) dt \quad (24)$$

$$\leq (1 + \Theta_2) \int_0^{z_\lambda(x^*, x_{n+1}^*)} \zeta(t) dt + (\Theta_1 + \Theta_2 + \Theta_4 + \Theta_6) \int_0^{z_\lambda(x_n, x^*)} \zeta(t) dt \quad (25)$$

$$+ (\Theta_5 + \Theta_6) \int_0^{z_\lambda(x^*, x_{n+1}^*)} \zeta(t) dt \quad (26)$$

$$\int_0^{z_\lambda(x^*, Tx^*)} \zeta(t) dt \leq 0 \quad (27)$$

as $n \rightarrow \infty$

x^* is the FP of T , and x' is the added FP of T .

Then, $Tx' = x'$

$$\int_0^{z_\lambda(x^*, x')} \zeta(t) dt = \int_0^{z_\lambda(Tx^*, Tx')} \zeta(t) dt \quad (28)$$

$$\leq \Theta_1 \int_0^{z_\lambda(x^*, x')} \zeta(t) dt + \Theta_2 \int_0^{z_\lambda(x^*, Tx^*)} \zeta(t) dt \quad (29)$$

$$+ \Theta_3 \int_0^{z_\lambda(x', Tx')} \zeta(t) dt + \Theta_4 \int_0^{z_\lambda(x^*, Tx')} \zeta(t) dt \quad (30)$$

$$+ \Theta_5 \int_0^{z_\lambda(x', Tx^*)} \zeta(t) dt + \Theta_6 \int_0^{[z_\lambda(x', Tx^*) + z_\lambda(x^*, Tx')]} \zeta(t) dt \quad (31)$$

$$\leq \Theta_1 \int_0^{z_\lambda(x^*, x')} \zeta(t) dt + \Theta_2 \int_0^{z_\lambda(x^*, x^*)} \zeta(t) dt + \Theta_3 \int_0^{z_\lambda(x', x')} \zeta(t) dt + \Theta_4 \int_0^{z_\lambda(x^*, x')} \zeta(t) dt \quad (32)$$

$$+ \Theta_5 \int_0^{z_\lambda(x', x^*)} \zeta(t) dt + \Theta_6 \int_0^{[z_\lambda(x', x^*) + z_\lambda(x^*, x')]} \zeta(t) dt \quad (33)$$

$$\int_0^{z_\lambda(x^*, x')} \zeta(t) dt \leq (\Theta_1 + \Theta_4 + \Theta_5 + 2\Theta_6) \int_0^{z_\lambda(x^*, x')} \zeta(t) dt \quad (34)$$

$$\Rightarrow x^* = x' \quad (35)$$

$\therefore T$ has a unique FP.

Proof 3: $X \rightarrow \neq \emptyset$, ' $z' \rightarrow$ MMS on X and $T: X_z^* \rightarrow X_z^*$ is defined as follows

$$z_{k\lambda}(Tx_1, Tx_2) \leq \Theta_1 z_\lambda(x_1, x_2) + \Theta_2 z_\lambda(x_1, Tx_1) + \Theta_3 z_\lambda(x_2, Tx_2) + \Theta_4 z_\lambda(x_1, Tx_1) + \Theta_5 z_\lambda(x_2, Tx_1) \quad (36)$$

$\lambda > 0$, $\exists$ an $a_0 \in X_z^* | w_\lambda(x_0, Tx_0) < \infty$ and $\zeta: [0, \infty) \rightarrow [0, \infty)$ be LIM | the mapping T has an FP in X_z^* . And, the FP of T is unique.

Proof: Put $\Theta_6 = 0$ in Proof 1, obtain the solution for this result.

3. Application

This section uses the FPT to ensure a Dynamic Programming (DP) result. Consequently, it derives a randomization-based dynamic routing result for secure WSNs. State Space (SS) and Decision Space (DS) are the two-state processes that set up DP. SS can be separated into three states: initial, transitional, and action. On the downside, DS includes the maintained process to restate the problem's result. Complementary algorithms have extensive applications in optimization. AWSN used to have 100 or 1000 detector bumps in it. Now and then, they communicate with one another and with a Base Station (BS) directly. Though they can detect cautiously in a common region, the threat is reduced if a network has more detectors. Sensor Nodes (SN) typically

communicate high-quality data while dispersed over a sizable sensor area. Figure 1 shows the dynamic programming using FPT [16].



Figure 1
Dynamic Programming using FPT

SN are tiny electronic devices with sensors to monitor several physical and environmental factors, like light, motion, vibration, temperature, humidity, and pollution. A microcontroller or microprocessor is usually present in every SN to manage data processing, make decisions, and perform control functions. SN can send data to BS or nearby nodes using WSN modules like Wi-Fi, Bluetooth, Zigbee, or LoRa. Since SNs are frequently used in severe locations, they run on batteries. Power management systems such as duty cycling, energy collecting, and sleep modes increase the node's battery life. A discrete network is formed by locating SN all around the monitored region. Depending on the application's requirements, they can be mobile or set in place. The BS serves as a central point for collecting data from SN within the WSN. It aggregates the data received from multiple nodes, reducing redundant transmissions and conserving energy. Depending on the application, the BS may perform further data processing, analysis, and decision-making. This could involve real-time analytics, anomaly detection, or event classification. The base station typically has higher processing power and long-distance communication resources than SN. It is a gateway between the WSN and external networks, such as the Internet or a Local Area Network (LAN). Unlike SN, BS are frequently connected to a reliable power source, such as mains electricity or solar panels, allowing them to operate continuously without relying on batteries. Base stations are purposefully located within the monitored area to ensure acceptable coverage and connectivity with SN. The number and location of BS depend on factors such as the size of the deployment area, the density of SN, and the communication range.

4. Conclusion

This study presents FPT in MMS for WSN. It aims to provide flexible distance measurements that consider periodicity and encompassing objects, which can be helpful in deployment settings. MMS can provide more robust routing and communication methods that adjust to the unique features of the environments. FPT can optimize network functions, including node placement, routing, data aggregation, and localization. Iterative methods can reach constant solutions because of network optimization problems such as FP. Incorporating FPT and MMS into WSNs can be central to innovative connectivity, scalability, and energy efficiency results. Routing algorithms can use the periodicity of

MMS to find effective paths between nodes, reducing energy consumption and extending network lifetime. Localization algorithms can use FP iterations to fine-tune node position predictions based on distance measurements in the MMS.

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Received February, 2024