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A CONTRIBUTION TO THE STUDY ON CHAOS SPACE IN FUZZY ROUGH ALGEBRAIC TM SYSTEM

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ABSTRACT

This paper introduces a new concept called chaos space in fuzzy rough algebraic TM system. It studies the properties of chaos space and introduces a new system called fuzzy rough chaotic structure space. It emphasizes the properties of chaotic interior and chaotic closure.

Keywords: fuzzy rough chaotic TM algebra, fuzzy rough algebraic chaos system, fuzzy rough algebraic chaotic closed, fuzzy rough algebraic chaotic open

1. Introduction

By R. L. Devaney [1], the idea of chaos in generic metric space was first proposed. Devaney's concept of chaos' foundational characteristics was formed. Additionally, the characteristics of chaos were developed and researched [3,4,5]. This chapter deals with the chaos space in fuzzy rough algebraic TM system. Some of its interesting properties were discussed.

2. Preliminaries:

Definition 2.1 [3]

Let $f: X \to X$ be any mapping and let X be a nonempty set. Give any fuzzy set in X, λ. Under the mapping f, the fuzzy orbit $O_f(\lambda)$ of λ is defined as $O_f(\lambda) = \{\lambda, f(\lambda), f^2(\lambda), \dots)$

Definition 2.2 [2]

Let $f: X \to X$ be any mapping and let X be a non-empty set. The intersection of all members of $O_f(\lambda)$ is defined as $FO_f(\lambda) = \{\lambda \wedge f(\lambda) \wedge f^2(\lambda) \wedge \dots\}$, which represents the fuzzy orbit set of λ under the mapping f.

Definition 2.3 [3]

Let (X, τ) be a fuzzy topological space. Let any mapping $f: X \to X$. Fuzzy orbit open set under the mapping f is the fuzzy orbit set under the mapping f that is in fuzzy topology τ. Under the mapping f, its complement is referred to as a fuzzy orbit closed set.

Definition 2.4 [5]

Let $f: X \to X$ be any mapping and let X be a nonempty set. If $f^n(\lambda) = \lambda$, for some $n \in Z_+$, then a fuzzy set λ of X is called a fuzzy periodic set with regard to f. Fuzzy periodic of X is the smallest of these n.

Definition 2.5 [4]

Let $f: X \to X$ be any mapping and let (X, τ) be a fuzzy topological space. Fuzzy-periodic open set with respect to f is the fuzzy periodic set with respect to f in fuzzy topology τ. Fuzzy periodic closed set with respect to f is the name of its complement.

3. FUZZY ROUGH ALGEBRAIC CHAOTIC STRUCTURE SPACE

Definition 3.1

Let $A = (A_L, A_U)$ be fuzzy rough algebraic of a fuzzy rough algebraic TM system. Then the fuzzy rough algebraic TM orbit of an algebraic B is denoted and defined by $\mathcal{O}_{TM}(B)$ of B is a mapping $\nmid\!f: A \to A$ such that $\mathcal{O}_{TM}(B) = \{B, \nmid\!f(B), \nmid\!f^2(B), \dots,\}$.

Definition 3.2

For a fuzzy rough algebraic TM system, let $A = (A_L, A_U)$ be its fuzzy rough algebraic. Under the mapping $\nmid\!f$, the fuzzy rough orbit algebraic of B is given by $F_{RTM}\mathcal{O}_{TM}(B) = (B \cap \nmid\!f(B) \cap \nmid\!f^2(B) \cap \dots\}$, which is the intersection of all elements of $\mathcal{O}_{TM}(B)$.

Definition 3.3

Let A be a fuzzy rough algebraic, $\nmid\!f: A \to A$ be any mapping, and (X, TM) be a fuzzy rough algebraic TM system. Fuzzy rough algebraic open orbit is the fuzzy rough orbit algebraic under the mapping $\nmid\!f$ that is in the fuzzy rough algebraic TM system. Under the mapping$\nmid\!f$, its complement is referred to as a fuzzy rough algebraic closed orbit.

Definition 3.4

A fuzzy rough algebraic A is called fuzzy rough periodic algebra of a fuzzy rough algebraic TM system with respect to the mapping $\nmid\!f: X \to X$ if $(\nmid\!f_{TM})^n(A) = A$, for least $n \in Z_+$.

Definition 3.5

Let $\nmid\!f: X \to X$ be any mapping and let (X, TM) be a fuzzy rough algebraic TM system. In the fuzzy rough algebraic TM system, the so-called fuzzy rough periodic algebra with respect to $\nmid\!f$ is referred to as the fuzzy rough algebraic periodic open, and its complement is referred to as the fuzzy rough algebraic periodic closed.

Notation 3.1.1

$F_{RTM}Pe = \bigcap$ {fuzzy rough algebraic periodic open with respect to $\nmid\!f$}.

Definition 3.6

A fuzzy rough algebraic A of a fuzzy rough algebraic TM system (X, TM) is said to fuzzy rough algebraic compact if and only if for all $\mathcal{B} \subset TM$ such that $sup_{B \in \mathcal{B}} B \geq A$ and for all $\varepsilon > 0$, there exists a finite subalgebra $\mathcal{B}_0 \subset \mathcal{B}$ such that $sup_{B \in \mathcal{B}_0} B \geq A - \epsilon$. The collection of all algebraic compact is denoted by $F\mathcal{G}_{TM}(X)$.

Definition 3.7

A fuzzy rough algebraic A in a fuzzy rough algebraic TM system (X, TM) is called fuzzy rough algebraic dense if there exists no fuzzy rough closed algebraic B in (X, TM) such that $A < B < 1$. That is, $F_{RTM}cl(A) = \tilde{1}$ in (X, TM).

Definition 3.8

Let (X, TM) be a fuzzy rough algebraic TM system and $A \in F\mathcal{G}_{TM}(X)$. Then the mapping $\mathfrak{f}: X \to X$ is said to be fuzzy rough chaotic TM algebra with respect to A if

(i) $F_{RTM}cl(F_{RTM}\mathcal{O}_{TM}(A)) = \tilde{1}$,

(ii) $F_{RTM}Pe$ is fuzzy rough algebraic dense.

Notation 3.1.2

(i) When A is a fuzzy rough algebraic in X, then $F_R\mathfrak{C}(A_{TM}) =\{\mathfrak{f}: X \to X / \mathfrak{f}$ is a fuzzy rough chaotic TM algebra with respect to A$\}$.

(ii) $F_R\mathfrak{CA}(X) = \{A \in F\mathcal{G}_{TM}(X) / F_R\mathfrak{C}(A_{TM}) \neq \tilde{0}$.

Definition 3.9

If $F_R\mathfrak{CA}(X) \neq \tilde{0}$, then a fuzzy rough algebraic TM system $(X, \mathfrak{CA}_{TM})$ is referred to as a fuzzy rough algebraic chaos system. The elements of $F_R\mathfrak{CA}(X)$ are referred to as fuzzy rough chaotic TM algebra in X if (X, TM) is a fuzzy rough algebraic chaos system.

Definition 3.10

Consider a fuzzy rough algebraic chaos system $(X, \mathfrak{CA}_{TM})$. Let $\mathfrak{S}$ be the set of fuzzy rough chaotic TM algebras in X that meet the requirements listed below:

(i) $\tilde{0}, \tilde{1} \in \mathfrak{S}$

(ii) If $A_1, A_2 \in \mathfrak{S}$, then $A_1 \cap A_2 \in \mathfrak{S}$.

(iii) If $\{A_j : j \in J\} \subset \mathfrak{S}$, then $\bigcup_{j \in J} A_j \in \mathfrak{S}$.

Then, in X, $\mathfrak{S}$ is referred to as the fuzzy rough algebraic chaotic structure, and the fuzzy rough algebraic chaotic structure space is denoted as $(\mathfrak{S}, \mathfrak{CA}_{TM})$. Fuzzy rough algebraic chaotic closed is the complement of $\mathfrak{S}$, while fuzzy rough algebraic chaotic open is the set of components that make up $\mathfrak{S}$.

Definition 3.11

Let $(X, \mathfrak{CA}_{TM})$ be a fuzzy rough algebraic chaos system. Let A be chaotic TM algebra in X. Then

(i) The fuzzy rough chaotic interior of A is defined and denoted as

$$F_R\mathfrak{CA}_{TM}int(A) = \bigcup \{B : A \supseteq B,\ \text{B is a fuzzy rough algebraic chaotic open}\}$$

(ii) The fuzzy rough chaotic closure of A is defined and denoted as

$$F_R\mathfrak{CA}_{TM}cl(A) = \bigcap \{B : A \subseteq B,\ B \text{ is a fuzzy rough algebraic chaotic closed}\}$$

Proposition 3.1.1

Let $(X, \mathfrak{C}\mathfrak{A}_{TM})$ be a fuzzy rough algebraic chaos system. Let D be chaotic TM algebra in X. Then the following statements hold:

(i) $F_R\mathfrak{C}\mathfrak{A}_{TM}int(D)$ is a fuzzy rough algebraic chaotic open.

(ii) $F_R\mathfrak{C}\mathfrak{A}_{TM}cl(D)$ is a fuzzy rough algebraic chaotic closed.

(iii) D is a fuzzy rough algebraic chaotic open if and only if $D = F_R\mathfrak{C}\mathfrak{A}_{TM}int(D)$.

Proof

The proof follows from the *Definition 3.11*

Remark 3.1.1

Let $(X, \mathfrak{C}\mathfrak{A}_{TM})$ be a fuzzy rough algebraic chaos system. Let D be chaotic TM algebra in X. Then the following statements hold:

(i) $F_R\mathfrak{C}\mathfrak{A}_{TM}int(D) \subseteq D \subseteq F_R\mathfrak{C}\mathfrak{A}_{TM}cl(D)$.

(ii) $\left(F_R\mathfrak{C}\mathfrak{A}_{TM}int(D)\right)' = F_R\mathfrak{C}\mathfrak{A}_{TM}cl(D)'$

(iii) $\left(F_R\mathfrak{C}\mathfrak{A}_{TM}cl(D)\right)' = F_R\mathfrak{C}\mathfrak{A}_{TM}int(D)'$

Proof

The proof is simple and obvious by *Proposition 3.1.1*.

Proposition 3.1.2

Let $\{D_j\}_{j\in J}$ be a family of chaotic TM algebra in X and J be an indexed set. Then for $j \in J$,

(i) $\cup_j F_R\mathfrak{C}\mathfrak{A}_{TM}cl(A_j) \subseteq F_R\mathfrak{C}\mathfrak{A}_{TM}cl\left(\cup_j (A_j)\right)$

(ii) $\cup_j F_R\mathfrak{C}\mathfrak{A}_{TM}int(A_j) \subseteq F_R\mathfrak{C}\mathfrak{A}_{TM}int\left(\cup_j (A_j)\right)$

Also, for any finite $n \in J$, $\cup_n F_R\mathfrak{C}\mathfrak{A}_{TM}cl(A_n) = F_R\mathfrak{C}\mathfrak{A}_{TM}cl(\cup_n (A_n))$.

Proof

The proof follows from *Definition 3.11*.

Proposition 3.1.3

Let $(X, \mathfrak{C}\mathfrak{A}_{TM})$ be a fuzzy rough algebraic chaos system. Let D and E be any two chaotic TM algebra in X. Then the following conditions hold:

(i) $F_R\mathfrak{C}\mathfrak{A}_{TM}int(D) \subseteq D$.

(ii) $D \subseteq E \Longrightarrow F_R\mathfrak{C}\mathfrak{A}_{TM}int(D) \subseteq F_R\mathfrak{C}\mathfrak{A}_{TM}int(E)$

(iii) $F_R\mathfrak{C}\mathfrak{A}_{TM}int\left(F_R\mathfrak{C}\mathfrak{A}_{TM}int(D)\right) = F_R\mathfrak{C}\mathfrak{A}_{TM}int(D)$

(iv) $F_R\mathfrak{C}\mathfrak{A}_{TM}int(D \cap E) = F_R\mathfrak{C}\mathfrak{A}_{TM}int(D) \cap F_R\mathfrak{C}\mathfrak{A}_{TM}int(E)$

(v) $F_R\mathfrak{C}\mathfrak{A}_{TM}int(\tilde{0}) = \tilde{0}$

(vi) $F_R\mathfrak{C}\mathfrak{A}_{TM}int(\tilde{1}) = \tilde{1}$

Proof

From *Definition 3.10 and 3.11* the proposition is proved.

Proposition 3.1.4

Let $(X, \mathfrak{CA}_{TM})$ be a fuzzy rough algebraic chaos system. Let A and B be be any two chaotic TM algebra in X. Then the following conditions hold:

(i) $A \subseteq F_R\mathfrak{CA}_{TM}cl(A)$.

(ii) $A \subseteq B \Longrightarrow F_R\mathfrak{CA}_{TM}cl(A) \subseteq F_R\mathfrak{CA}_{TM}cl(B)$

(iii) $F_R\mathfrak{CA}_{TM}cl\big(F_R\mathfrak{CA}_{TM}cl(A)\big) = F_R\mathfrak{CA}_{TM}cl(A)$

(iv) $F_R\mathfrak{CA}_{TM}cl(A \cup B) = F_R\mathfrak{CA}_{TM}cl(A) \cup F_R\mathfrak{CA}_{TM}cl(B)$

(v) $F_R\mathfrak{CA}_{TM}cl(\tilde{0}) = \tilde{0}$

(vi) $F_R\mathfrak{CA}_{TM}cl(\tilde{1}) = \tilde{1}$

Proof

The proposition is proved from *Definition 3.10 and 3.11*.

Proposition 3.1.5

(i) Any finite intersection of fuzzy rough algebraic chaotic open is a fuzzy rough algebraic chaotic open.

(ii) Any finite union of fuzzy rough algebraic chaotic closed is fuzzy rough algebraic chaotic closed.

Proof

(i) Let $\{B_j\}_{j=1}^{n}$ be a finite collection of fuzzy rough algebraic chaotic open. Then for each j, $F_R\mathfrak{CA}_{TM}int(B) = F_R\mathfrak{CA}_{TM}int\big(F_R\mathfrak{CA}_{TM}cl(B)\big)$.

Now, by hypothesis and *Proposition 3.1.2*.

$$F_R\mathfrak{CA}_{TM}int\big(\cap_{j=1}^{n} B_j\big) = \cap_{j=1}^{n} F_R\mathfrak{CA}_{TM}int(B_j)$$
$$= \cap_{j=1}^{n} F_R\mathfrak{CA}_{TM}int\big(F_R\mathfrak{CA}_{TM}cl(B_j)\big)$$
$$= F_R\mathfrak{CA}_{TM}int\left(\cap_{j=1}^{n}\left(F_R\mathfrak{CA}_{TM}cl(B_j)\right)\right)$$
$$\supseteq F_R\mathfrak{CA}_{TM}int\left(F_R\mathfrak{CA}_{TM}cl\big(\cap_{j=1}^{n} B_j\big)\right).$$

On the other hand, $\cap_{j=1}^{n} B_j \subseteq F_R\mathfrak{CA}_{TM}cl\big(\cap_{j=1}^{n} B_j\big)$

Which implies,

$$F_R\mathfrak{CA}_{TM}int\big(\cap_{j=1}^{n} B_j\big) \subseteq F_R\mathfrak{CA}_{TM}int\left(F_R\mathfrak{CA}_{TM}cl\big(\cap_{j=1}^{n} B_j\big)\right).$$

Therefore,

$$F_R\mathfrak{CA}_{TM}int\big(\cap_{j=1}^{n} B_j\big) = F_R\mathfrak{CA}_{TM}int\left(F_R\mathfrak{CA}_{TM}cl\big(\cap_{j=1}^{n} B_j\big)\right).$$

Hence any finite intersection of fuzzy rough algebraic chaotic open is a fuzzy rough algebraic chaotic open.

(ii) Let $\{D_j\}_{j=1}^{n}$ be a finite collection of

fuzzy rough algebraic chaotic closed. Then for each j, $F_R\mathfrak{CA}_{TM}cl(A) = F_R\mathfrak{CA}_{TM}cl\big(\mathcal{F}_{\mathcal{RTM}}int(A)\big)$.

Now, by hypothesis and *Proposition 3.1.4*.

$$F_R\mathfrak{CA}_{TM}cl\left(\cup_{j=1}^{n} A_j\right) = \cup_{j=1}^{n} F_R\mathfrak{CA}_{TM}cl(A_j)$$
$$= \cup_{j=1}^{n} F_R\mathfrak{CA}_{TM}cl\left(F_R\mathfrak{CA}_{TM}int(A_j)\right)$$
$$= F_R\mathfrak{CA}_{TM}cl\left(\cup_{j=1}^{n}\left(F_R\mathfrak{CA}_{TM}int(A_j)\right)\right)$$
$$\subseteq F_R\mathfrak{CA}_{TM}cl\left(F_R\mathfrak{CA}_{TM}int\left(\cup_{j=1}^{n} A_j\right)\right).$$

On the other hand,

$$F_R\mathfrak{CA}_{TM}int\left(\cup_{j=1}^{n} A_j\right) \subseteq \cup_{j=1}^{n} A_j$$

Which implies,

$$F_R\mathfrak{CA}_{TM}cl\left(F_R\mathfrak{CA}_{TM}int\left(\cup_{j=1}^{n} A_j\right)\right) \subseteq F_R\mathfrak{CA}_{TM}cl\left(\cup_{j=1}^{n} A_j\right).$$

Therefore, $F_R\mathfrak{CA}_{TM}cl\left(\cup_{j=1}^{n} A_j\right) = F_R\mathfrak{CA}_{TM}cl\left(F_R\mathfrak{CA}_{TM}int\left(\cup_{j=1}^{n} A_j\right)\right)$. Hence any finite rough algebraic closed is a fuzzy rough algebraic closed.

Definition 3.12

Let $(X, \mathfrak{CA}_{TM})$ be a fuzzy rough algebraic chaos system. Then $(X, \mathfrak{CA}_{TM})$ is called a fuzzy rough algebraic regular chaos system if the fuzzy rough chaotic closure of every fuzzy rough chaotic TM algebra is a fuzzy rough chaotic TM algebra.

Proposition 3.1.6

Let $(X, \mathfrak{CA}_{TM})$ be a fuzzy rough algebraic chaos system. Then the following statements are equivalent:

(i) $(X, \mathfrak{CA}_{TM})$ is a fuzzy rough algebraic regular chaos system.

(ii) For each fuzzy rough algebraic chaotic closed D, $F_R\mathfrak{CA}_{TM}int(D)$ is a fuzzy rough algebraic chaotic closed.

(iii) For each fuzzy rough algebraic chaotic open B,

$$F_R\mathfrak{CA}_{TM}cl(B) \cup F_R\mathfrak{CA}_{TM}cl(F_R\mathfrak{CA}_{TM}cl(B)') = \tilde{1}.$$

(iv) For every pair of fuzzy rough algebraic chaotic open S and R with $F_R\mathfrak{CA}_{TM}cl(A) \cup B = \tilde{1}$, $F_R\mathfrak{CA}_{TM}cl(A) \cup F_R\mathfrak{CA}_{TM}cl(B) = \tilde{1}$.

Proof

(i) ⇒ (ii)

Let D be any fuzzy rough algebraic chaotic closed in X. Then D' is a fuzzy rough algebraic chaotic open.

Hence, $F_R\mathfrak{CA}_{TM}cl(D)' = \left(F_R\mathfrak{CA}_{TM}int(D)\right)'$.

Then by (i) $F_R\mathfrak{CA}_{TM}cl(D)'$ is a fuzzy rough algebraic chaotic open. Then $F_R\mathfrak{CA}_{TM}int(D)$ is fuzzy rough algebraic chaotic closed.

(ii) ⇒ (iii)

Let B be a fuzzy rough algebraic chaotic open. Then,

$$F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl\left(F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B)\right)'$$
$$= F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl(F_R\mathfrak{C}\mathfrak{A}_{TM}int(B)') \quad (1)$$

Since B is a fuzzy rough algebraic chaotic open, B' is a fuzzy rough algebraic chaotic closed. Hence by (ii), $F_R\mathfrak{C}\mathfrak{A}_{TM}int(B)'$ is a fuzzy rough algebraic chaotic closed.

Then by *Equation (1),*

$$F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl\left(F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B)\right)'$$
$$= F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl(F_R\mathfrak{C}\mathfrak{A}_{TM}int(B)')$$
$$= F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}int(B)'$$
$$= F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B) \cup \left(F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B)\right)'$$
$$= \tilde{1}.$$

Hence $F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl\left(F_R\mathfrak{C}\mathfrak{A}_{TM}cl(B)\right)' = \tilde{1}$.

(iii) ⇒ (iv)

Let S and R fuzzy rough algebraic chaotic open with

$$F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S) \cup R = \tilde{1}. \quad (2)$$

By (iii), $\tilde{1} = F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl\left(F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S)\right)'$

$$= F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl\left(F_R\mathfrak{C}\mathfrak{A}_{TM}cl(R)\right)'$$
$$= F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl(R).$$

Hence, $F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S) \cup F_R\mathfrak{C}\mathfrak{A}_{TM}cl(R) = \tilde{1}$.

(iv) ⇒ (i)

Let S be a fuzzy rough algebraic chaotic open.

Take $R = \left(F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S)\right)'$. Then $F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S) \cup R = \tilde{1}$.

This implies that $F_R\mathfrak{C}\mathfrak{A}_{TM}cl(S)$ is a fuzzy rough algebraic chaotic open and so $(X, \mathfrak{C}\mathfrak{A}_{TM})$ is a fuzzy rough algebraic regular chaos system.

Conclusion:

This work would like to make the upbeat prediction that the proposed definitions and findings of this work can be similarly applied to additional TM-ideals in different structure space. This study will be useful in generating a big impression on prospective researchers, pique their interest in this area and related ones, and broaden their frontiers of knowledge.

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