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On Zweier $\mathcal{J}$-convergent sequence spaces defined by Orlicz function in neutrosophic normed linear spaces

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Abstract

In this article we define and develop Zweier $\mathcal{J}$-convergent sequence spaces: $\mathcal{Z}_{(\mathfrak{M},\mathfrak{R},\mathfrak{B})}(\mathcal{J}:\mathrm{O})$ and $\mathcal{Z}_{0(\mathfrak{M},\mathfrak{R},\mathfrak{B})}(\mathcal{J}:\mathrm{O})$ using Orlicz function in neutrosophic normed linear spaces. We also study some topological property of these spaces.

Subject Classification: *40A35, 40A05, 46B20.*

Keywords: *$\mathcal{J}$-convergent, Orlicz function, Neutrosophic normed linear spaces.*

1. Introduction

In 1965, Zadeh [33] introduced the idea of fuzzy sets which are successfully applied in many engineering fields, including social dynamics [5], computer science [11], irregular dynamic system [13], chaos control [9]. Some generalizations of fuzzy sets have been appeared in literature (see [4], [8], [27], [1-3], [6], [12], [15], [20], [32]).

The idea of sequence spaces has been introduced in generalized normed spaces such as fuzzy, intuitionistic fuzzy and neutrosophic normed linear spaces. For a detail study on these spaces, we refer [10], [12], [17], [20]-[23], [25], [26], [29]-[31]. In this paper we define some Zweier $\mathcal{I}$-convergent space in neutrosophic normed spaces and study some of their topological properties.

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2. Preliminaries

We begin with the following definition of statistical convergence due to Fast [7]. A sequence (x_k) of numbers is said to be statistically convergent to x_0 if for every $\epsilon > 0$ the set $K = \{n \in \mathbb{N}: |x_k - x_0| \geq \epsilon\}$ has a natural density zero. Kostyrko et al [19], generalized statistical convergence by using ideal as follows: Let X be a non-empty set and power set and the power set of X is $P(X)$. A family of sets $\mathcal{I} \subseteq P(X)$ is said to be an ideal on X, if $\mathcal{I}$ is additive, i.e., $D, E \in \mathcal{I} \Rightarrow D \cup E \in \mathcal{I}$ and hereditary, i.e.,$D \in \mathcal{I}, E \subseteq D \Rightarrow E \in \mathcal{I}$. A family of sets $\mathcal{F} \subset P(X)$ is said to be filter on X, if $\phi \notin \mathcal{F}$, for $D, E \in \mathcal{F}$ we have $D \cap E \in \mathcal{F}$ and for each $D \in \mathcal{F}$ and $E \supset D \Rightarrow E \in \mathcal{F}$. A sequence (x_k) of numbers is said to be ideal convergent to x_0 if for every $\epsilon > 0$ the set $K = \{k \in \mathbb{N}: |x_k - x_0| \geq \epsilon\} \in \mathcal{I}$.

By an Orlicz function we mean a function $O: [0, \infty) \to [0, \infty)$, which is continuous, non-decreasing and convex with $O(0) = 0, O(p) > 0$ for $p > 0$ and $O(p) \to \infty$ as $p \to \infty$ [19].

Şengönül [28] used $\mathcal{Z}^p$ transformation of the sequence $x = (x_k)$ to define a new sequence $y = (y_k)$ by

$$y_k = px_k + (1-p)x_{k-1}$$

Where $x_{k-1} = 0, 1 < p < \infty$ and $\mathcal{Z}^p = (z_{kj})$ defined by

$$z_{kj} \begin{cases} p, (k = j) \\ 1-p, \quad (k-1 = j: (k, j \in \mathbb{N})) \\ 0, \quad \text{otherwise} \end{cases}$$

Using $\mathcal{Z}^p$ transform Şengönül [28] define the following spaces, $\mathcal{Z} = \{x = (x_k) \in \xi: \mathcal{Z}^p(x) \in c$, $\mathcal{Z}_0 = \{x = (x_k) \in \xi: \mathcal{Z}^p(x) \in c_0$. Where, ξ denotes set of all the sequence in neutrosophic normed linear space. After their pioneer work several papers have been appeared to define new sequence spaces by use of $\mathcal{Z}^p$ transform, Orlicz function and certain generalized convergences such as statistical and ideal convergence. A few among these can be seen in [14]-[16].

Kirişçi and Şimşek used t-norm and t-conorm to define neutrosophic norm linear spaces. for detail study of neutrosophic normed linear spaces, we refer [18][24].

Let $(X, \mathfrak{M}, \mathfrak{N}, \mathfrak{P}, \star, *)$ be a NNLS, $\eta \in (0,1), \zeta > 0$ and $u \in X$. Then the set

$$\mathcal{S}_u(\varepsilon, \zeta) = \{v \in X: \{k: \mathbb{N}: \mathfrak{M}(u - v, \zeta) \leq 1 - \varepsilon \text{ or } \mathfrak{N}(u - v, \zeta) \geq \varepsilon, \\ \mathfrak{P}(u - v, \zeta) \geq \varepsilon\} \in \mathcal{I}\}$$

is define as open ball with center u and radius ε with respect to ζ.

3. Main Results

In this section we give our main results. We start by defining the following sequence spaces in neutrosophic normed linear spaces.

$\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}: O) =$

$\Big\{ (u_k) \in \xi : \Big\{ k \in \mathbb{N} : O\left(\frac{\mathfrak{M}(\mathcal{Z}^p(u_k)-u_0,\zeta)}{\varsigma}\right) \le 1-\eta$ and $O\left(\frac{\mathfrak{n}(\mathcal{Z}^p(u_k)-u_0,\zeta)}{\varsigma}\right) \ge \eta,$
$O\left(\frac{\mathfrak{P}(\mathcal{Z}^p(u_k)-u_0,\zeta)}{\varsigma}\right) \ge \eta \Big\} \in \mathcal{I} \Big\},$

$\mathcal{Z}_{0(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}:O) =$
$\Big\{ (v_k) \in \xi : \Big\{ k \in \mathbb{N} : O\left(\frac{\mathfrak{M}(\mathcal{Z}^p(v_k)-v_0,\zeta)}{\varsigma}\right) \le 1-\eta$ and $O\left(\frac{\mathfrak{n}(\mathcal{Z}^p(v_k)-v_0,\zeta)}{\varsigma}\right) \ge \eta,$
$O\left(\frac{\mathfrak{P}(\mathcal{Z}^p(v_k)-v_0,\zeta)}{\varsigma}\right) \ge \eta \Big\} \in \mathcal{I} \Big\}.$

Now for the author convenient and throughout the paper we will use $\mathcal{Z}^p(u_k) = u'_k$ and $\mathcal{Z}^p(v_k) = v'_k$ for $u, v \in \xi$.

$\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}:O) =$
$\Big\{ (u_k) \in \xi : \Big\{ k \in \mathbb{N} : O\left(\frac{\mathfrak{M}(u'_k-u_0,\zeta)}{\varsigma}\right) \le 1-\eta$ and $O\left(\frac{\mathfrak{n}(u'_k-u_0,\zeta)}{\varsigma}\right) \ge \eta,$
$O\left(\frac{\mathfrak{P}(u'_k-u_0,\zeta)}{\varsigma}\right) \ge \eta \Big\} \in \mathcal{I} \Big\},$

$\mathcal{Z}_{0(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}:O) =$
$\Big\{ (v_k) \in \xi : \Big\{ k \in \mathbb{N} : O\left(\frac{\mathfrak{M}(v'_k-v_0,\zeta)}{\varsigma}\right) \le 1-\eta \ and \ O\left(\frac{\mathfrak{n}(v'_k-v_0,\zeta)}{\varsigma}\right) \ge \eta,$
$O\left(\frac{\mathfrak{P}(v'_k-v_0,\zeta)}{\varsigma}\right) \ge \eta \Big\} \in \mathcal{I} \Big\}.$

Theorem 3.1: *$\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}:O)$ and $\mathcal{Z}_{0(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}:O)$ are normed linear spaces.*

Proof: Omitted.

Theorem 3.2: Every open ball $\mathcal{S}_{u'}(\varepsilon,\varsigma)$ is an open set in $\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}:O)$.

Proof: Let $\mathcal{S}_{u'}(\varepsilon,\varsigma)$ be an open ball with center u' and ϵ with respect to ς that is

$\mathcal{S}_{u'}(\varepsilon,\varsigma) =$
$\Big\{ v \in X : \Big\{ k \in \mathbb{N} : O\left(\frac{\mathfrak{M}(u'_k-v'_k,\zeta)}{\varsigma}\right) \le 1-\varepsilon \ or \ O\left(\frac{\mathfrak{N}(u'_k-v'_k,\zeta)}{\varsigma}\right) \ge \varepsilon$ and $O\left(\frac{\mathfrak{P}(u'_k-v'_k,\zeta)}{\varsigma}\right) \ge$
$\varepsilon \Big\} \in \mathcal{I} \Big\}.$

Let $v' \in \mathcal{S}^C_{u'}(\varepsilon,\varsigma)$. Then $O\left(\frac{\mathfrak{M}(u'-v',\zeta)}{\varsigma}\right) > 1-\varepsilon$ and $O\left(\frac{\mathfrak{N}(u'-v',\zeta)}{\varsigma}\right) < \varepsilon$, $O\left(\frac{\mathfrak{P}(u'-v',\zeta)}{\varsigma}\right) < \varepsilon$.

Since $O\left(\frac{\mathfrak{M}(u'-v',\zeta)}{\varsigma}\right) > 1-\varepsilon$, there exist $\zeta_0 \in (0,1)$ such that $O\left(\frac{\mathfrak{M}(u'-v',\zeta_0)}{\varsigma}\right) >$ 1-ε and $O\left(\frac{\mathfrak{N}(u'-v',\zeta_0)}{\varsigma}\right) < \varepsilon$, $O\left(\frac{\mathfrak{P}(u'-v',\zeta_0)}{\varsigma}\right) < \varepsilon$. Putting $\varepsilon = \left(\frac{\mathfrak{M}(u'-v',\zeta)}{\varsigma}\right)$ then $\varepsilon_0 > 1-\varepsilon$. Thus $\exists\ 0 < s < 1$ such that $\varepsilon_0 > 1-s > 1-\varepsilon$. For $\varepsilon_0 > 1-s, \exists\ \varepsilon_1, \varepsilon_2 \in (0,1)$ such that $\varepsilon_0 \star \varepsilon_1 > 1-s$ and $(1-\varepsilon_0) *$

$(1-\varepsilon_2) \leq s$. Putting $\varepsilon_3 = \max\{\varepsilon_1, \varepsilon_2\}$ and consider the ball $\mathcal{S}_{u'}^{\mathcal{C}}(1-\varepsilon_3, \zeta - \zeta_0)$. We prove that $\mathcal{S}_{v'}^{\mathcal{C}}(1-\varepsilon_3, \zeta-\zeta_0) \subset \mathcal{S}_{u'}^{\mathcal{C}}(\varepsilon, \varsigma)$.

Let $z' \in \mathcal{S}_{v'}^{\mathcal{C}}(1-\varepsilon_3, \zeta-\zeta_0)$. Then $O\left(\frac{\mathfrak{M}(v'-z',\ \zeta-\zeta_0)}{\varsigma}\right) > \varepsilon_3$ and $O\left(\frac{\mathfrak{N}(v'-z',\ \zeta-\zeta_0)}{\varsigma}\right) < \varepsilon_3, O\left(\frac{\mathfrak{P}(v'-z',\ \zeta-\zeta_0)}{\varsigma}\right) < \varepsilon_3$.

Thus, $O\left(\frac{\mathfrak{M}(u'-z',\zeta)}{\varsigma}\right) \geq O\left(\frac{\mathfrak{M}(u'-v',\zeta_0)}{\varsigma}\right) \star O\left(\frac{\mathfrak{M}(v'-z',\ \zeta-\zeta_0)}{\varsigma}\right)(1-\varepsilon_0) \star (1-\varepsilon_3) \geq (\varepsilon_0 \star \varepsilon_0) \geq 1-s > 1-\varepsilon$.

And $O\left(\frac{\mathfrak{N}(u'-z',\zeta)}{\varsigma}\right) \leq O\left(\frac{\mathfrak{N}(u'-v',\zeta_0)}{\varsigma}\right) * O\left(\frac{\mathfrak{N}(v'-z',\ \zeta-\zeta_0)}{\varsigma}\right) \leq (1-\varepsilon_0) * (1-\varepsilon_2) \leq (1-\varepsilon_0) * (1-\varepsilon_2) \leq s < \varepsilon$,

$O\left(\frac{\mathfrak{P}(u'-z',\zeta)}{\varsigma}\right) \leq O\left(\frac{\mathfrak{P}(u'-v',\zeta_0)}{\varsigma}\right) * O\left(\frac{\mathfrak{P}(v'-z',\ \zeta-\zeta_0)}{\varsigma}\right) \leq (1-\varepsilon_0) * (1-\varepsilon_2) \leq (1-\varepsilon_0) * (1-\varepsilon_2) \leq s < \varepsilon$,

So $z' \in \mathcal{S}_{v'}^{\mathcal{C}}(1-\varepsilon_3, \zeta-\zeta_0)$. Hence $\mathcal{S}_{v'}^{\mathcal{C}}(1-\varepsilon_3, \zeta-\zeta_0) \subset \mathcal{S}_{u'}^{\mathcal{C}}(\varepsilon, \varsigma)$.

Theorem 3.3: *A sequence $u = (u_n) \in \mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)$ $\mathcal{J}$-converges iff for every $\eta > 0$ and $\zeta > 0$ $\exists$ a number $N = N(u, \eta, \varsigma)$ such that*

$$\left\{k \in \mathbb{N}: O\left(\frac{\mathfrak{M}\left(u'_k - u_0, \frac{\zeta}{2}\right)}{\varsigma}\right) \leq 1-\eta \text{ or } O\left(\frac{\mathfrak{n}\left(u'_k - u_0, \frac{\zeta}{2}\right)}{\varsigma}\right) \geq \eta,\ O\left(\frac{\mathfrak{P}\left(u'_k - u_0, \frac{\zeta}{2}\right)}{\varsigma}\right) \geq \eta\right\} \in \mathcal{F}(\mathcal{J}).$$

Proof: Omitted.

Remark 3.4: Let $\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)$ be a NNLS. Define $\tau_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O) = \{A \subset [\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)\ ]$: for each $u \in A$, we can find ζ and $0 < \varepsilon < 1$ such that $[\mathcal{S}_{u'}(\mathcal{J}: O)] \subset A\}$. Then $\tau_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)$ is a topology on $\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)$.

Remark 3.5: Since $\{\mathcal{S}_{u'}\left(\frac{1}{n}, \frac{1}{n}\right)(\mathcal{J}: O): n \in \mathbb{N}\}$ is a local base at u', the topology $\tau_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)$ on $\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)$ is first countable.

Theorem 3.6: $\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)$ and $\mathcal{Z}_{0(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)$ are Housdroff spaces.

Proof: Let $u', v' \in [\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{J}: O)]$ such that $u' \neq v'$. Then $0 < O\left(\frac{\mathfrak{M}(u'-v',\zeta)}{\varsigma}\right) < 1$ and $0 < O\left(\frac{\mathfrak{N}(u'-v',\zeta)}{\varsigma}\right) < 1$, $0 < O\left(\frac{\mathfrak{P}(u'-v',\zeta)}{\varsigma}\right) < 1$. Putting $\varepsilon_1 = O\left(\frac{\mathfrak{M}(u'-v',\zeta)}{\varsigma}\right)$ and $\varepsilon_2 = O\left(\frac{\mathfrak{N}(u'-v',\zeta)}{\varsigma}\right)$, $\varepsilon_3 = O\left(\frac{\mathfrak{P}(u'-v',\zeta)}{\varsigma}\right)$ and $\varepsilon = \max\{\varepsilon_1, 1-\varepsilon_2, 1-\varepsilon_3\}$. Then for each $\varepsilon_0 \in (\in, 1), \exists\ \varepsilon_4$ and ε_5 such that

$$\varepsilon_4 \star \varepsilon_5 \geq \varepsilon_0 \text{ and } (1-\varepsilon_4) \star (1-\varepsilon_5) \leq (1-\varepsilon_0)$$

Putting $\varepsilon_6 = \max\{\varepsilon_4, 1-\varepsilon_5\}$. And consider the open ball $\mathcal{S}_{u'}^{\mathcal{C}}(1-\varepsilon_6, \frac{\zeta}{2})$ and $\mathcal{S}_{v'}^{\mathcal{C}}(1-\varepsilon_6, \frac{\zeta}{2})$ then the clearly $\mathcal{S}_{u'}^{\mathcal{C}}\left(1-\varepsilon_6, \frac{\zeta}{2}\right) \cap \mathcal{S}_{v'}^{\mathcal{C}}\left(1-\varepsilon_6, \frac{\zeta}{2}\right) = \phi$.

For if $\exists\ w' \in \mathcal{S}^{\,c}_{u'}\left(1-\varepsilon_6, \frac{\zeta}{2}\right) \cap \mathcal{S}^{\,c}_{v'}(1-\varepsilon_6, \frac{\zeta}{2})$, then

$$\varepsilon_1 = O\left(\frac{\mathfrak{M}(u'-v',\zeta)}{\varsigma}\right) \geq O\left(\frac{\mathfrak{M}\left(u'-w',\frac{\zeta}{2}\right)}{\varsigma}\right) \star O\left(\frac{\mathfrak{M}\left(w'-v',\frac{\zeta}{2}\right)}{\varsigma}\right)$$
$$\geq \varepsilon_6 \star \varepsilon_6 \geq \varepsilon_4 \star \varepsilon_4 \geq \varepsilon_0 > \varepsilon_1$$

And

$$\varepsilon_2 = O\left(\frac{\mathfrak{N}(u'-v',\zeta)}{\varsigma}\right) \geq O\left(\frac{\mathfrak{N}\left(u'-w',\frac{\zeta}{2}\right)}{\varsigma}\right) \star O\left(\frac{\mathfrak{N}\left(w'-v',\frac{\zeta}{2}\right)}{\varsigma}\right)$$
$$,\geq (1-\varepsilon_6) * (1-\varepsilon_6) \geq (1-\varepsilon_5) * (1-\varepsilon_5) \geq (1-) > \varepsilon_1,$$
$$\varepsilon_3 = O\left(\frac{\mathfrak{P}(u'-v',\zeta)}{\varsigma}\right) \geq O\left(\frac{\mathfrak{P}\left(u'-w',\frac{\zeta}{2}\right)}{\varsigma}\right) \star O\left(\frac{\mathfrak{P}\left(w'-v',\frac{\zeta}{2}\right)}{\varsigma}\right),$$
$$\geq (1-\varepsilon_6) * (1-\varepsilon_6) \geq (1-\varepsilon_5) * (1-\varepsilon_5) \geq (1-) > \varepsilon_1.$$

Contradict our assumption. So $[\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}\colon O)]$ is a Housdroff space. Similarly, $[\mathcal{Z}_{(\mathfrak{M},\ \mathfrak{N},\ \mathfrak{P})}(\mathcal{I}\colon O)]$ is a Housdroff space.

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