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An Approach for the Stone–Céch Type Compactifications of Plain Texture Spaces

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Abstract

In this study, the authors present an approach for the construction of a Stone–Céch type compactification of plain ditopological texture spaces in terms of difunctions.

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1 Introduction

A texturing on a set S is a point separating, complete, completely distributive lattice $\mathcal{S}$ of subsets of S with respect to inclusion which contains $S, \emptyset$ and, for which arbitrary meet coincides with intersection and finite joins coincide with union. Then $(S, \mathcal{S})$ is called a texture space. For $s \in S$ the set P_s is defined by $P_s = \bigcap\{A \mid s \in A \in \mathcal{S}\}$. Dually we define the set $Q_s \in \mathcal{S}$ by $Q_s = \bigvee\{P_t \mid s \notin P_t\}$ for every $s \in S$. $(S, \mathcal{S})$ is called *plain* if arbitrary join coincides with union, namely $P_s \not\subseteq Q_s$ for every $s \in S$ [3]. Let (f, F) be a

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direlation [5] from $(S, \mathcal{S})$ to $(T, \mathcal{T})$. Then (f, F) is called a *difunction* from $(S, \mathcal{S})$ to $(T, \mathcal{T})$ if

1. for $s, s' \in S$, $P_s \not\subseteq Q_{s'} \Rightarrow \exists\, t \in T$ with $f \not\subseteq \overline{Q}_{(s,t)}$ and $\overline{P}_{(s',t)} \not\subseteq F$.

2. for $t, t' \in T$ and $s \in S$, $f \not\subseteq \overline{Q}_{(s,t)}$ and $\overline{P}_{(s,t')} \not\subseteq F \Rightarrow P_{t'} \not\subseteq Q_t$.

It is known that difunctions and textures form a category which is denoted by **dfTex** [5]. A *ditopology* [3] on a texture space $(S, \mathcal{S})$ is a pair (τ, κ) of subsets of $\mathcal{S}$, where the family of *open sets* τ satisfies

(i) $S, \emptyset \in \tau$,

(ii) $G_1, G_2 \in \tau \Rightarrow G_1 \cap G_2 \in \tau$ and

(iii) $G_i \in \tau,\ i \in I \Rightarrow \bigvee_i G_i \in \tau$,

and the family of *closed sets* κ satisfies

(i) $S, \emptyset \in \kappa$,

(ii) $K_1, K_2 \in \kappa \Rightarrow K_1 \cup K_2 \in \kappa$ and

(iii) $K_i \in \kappa,\ i \in I \Rightarrow \bigcap K_i \in \kappa$.

Let $A \subseteq S$. Then we define

$$[A]^\kappa = \bigcap \{F \mid A \subseteq F,\ F \in \kappa\} (\kappa - \text{closure})$$

and

$$]A[^\tau = \bigvee \{G \mid G \subseteq A,\ G \in \tau\} (\tau - \text{interior}).$$

Definition 1.1 [2] Let $(S, \mathcal{S}, \tau, \kappa)$ and $(T, \mathcal{T}, u, v)$ be ditopological texture spaces and (f, F) be a difunction from S to T . Then (f, F) is called a *diembedding* from S to T if there exists a bidense ditopological principle subtexture $(N, \mathcal{T}_N, u_N, v_N)$ of $(T, \mathcal{T}, u, v)$ such that $(f_{S\times N}, F_{S\times N}) : (S, \mathcal{S}) \to (N, \mathcal{T}_N)$ is a dihomeomorphism. If $(T, \mathcal{T}, u, v)$ is dicompact, then $((f, F), (T, \mathcal{T}, u, v))$ is called *a dicompactification* of $(S, \mathcal{S})$.

Lemma 1.2 [5] *Let $(S, \mathcal{S})$, $(T, \mathcal{T})$ be textures and $\psi : S \to T$ be point function satisfying the following conditions:*

(a) $s, s' \in S, P_s \not\subseteq Q_{s'} \Rightarrow P_{\psi(s)} \not\subseteq Q_{\psi(s')}$.

(b) $P_{\psi(s)} \not\subseteq B, B \in \tau \Rightarrow \exists s' \in S$ *with* $P_s \not\subseteq Q_{s'}$ *for which* $P_{\psi(s')} \not\subseteq B$.

(c) *For* $A \in \tau$ *and* $s \in S^\flat$ *we have* $A \not\subseteq Q_{\psi(s)} \Rightarrow A \not\subseteq Q_{\psi(u)}$ *for some* $P_u \not\subseteq Q_s$.

Then the difunction (f_ψ, F_ψ) *corresponding to* ψ *satisfies the equalities*

$$f_\psi = \bigvee\{\overline{P}_{(s,\psi(s))} \mid s \in S\} \text{ and } G_\psi = \bigcap\{\overline{Q}_{(s,\psi(s))} \mid s \in S\}.$$

Further, $f_\psi^{\leftarrow} A = F_\psi^{\leftarrow} A = \psi^{-1}(A)$ *for all* $A \in \mathcal{T}$.

If we take the textures in Lemma 1.2 as plain textures, then any point function satisfies the conditions (b) and (c). As a result, we may say that plain textures and the point functions satisfying (a), form a category which is denoted by **fPTex**. Further, the category of ditopological plain texture spaces and continuous point functions is denoted by **fPDitop** [5] .

Definition 1.3 [1] A ditopological texture space $(S, \mathcal{S}, \tau, \kappa) \in$ Ob **fPDitop** is called

(i) *completely regular* if given $G \in \tau, G \not\subseteq Q_s$, there exists a bicontinuous function $\psi : S \to \mathbb{I}$ satisfying $\psi(P_s) = \{0\}$ and $\psi(S \setminus G) = \{1\}$.

(ii) *completely co–regular* if given $K \in \kappa, P_s \not\subseteq K$, there exists a bicontinuous function $\psi : S \to \mathbb{I}$ satisfying $\psi(S \setminus Q_s) = \{1\}$ and $\psi(K) = \{0\}$.

(iii) *completely biregular* if it is completely regular and completely co–regular.

Recall that the category of plain ditopological texture spaces and bicontinuous difunctions is denoted by **dfPDitop** [6].

Theorem 1.4 [1] $(S, \mathcal{S}, \tau, \kappa)$ is completely biregular in **fPDitop** if and only if it is completely biregular in **dfPDitop**.

Theorem 1.5 [3] If a ditopological texture space $(S, \mathcal{S}, \tau, \kappa)$ is bi–$T_{3\frac{1}{2}}$, then there exists a bicontinuous and injective difunction from S to the Tychonoff dicube.

For more details and the concepts which are not explained here, the reader is due to [4-8].

2 The Stone–Cěch Compactification

Theorem 2.1 *Let* $\psi \in$ *Mor* **fPTex** *and* $\psi(S) \in \mathcal{T}$. *Then*

(i) $f_\psi^{\rightarrow} S = \psi(S)$.

(ii) $((f_\psi)_{S\times\psi(S)}, (F_\psi)_{S\times\psi(S)})$ *is surjective.*

Proof (i) Suppose that $f_\psi^{\rightarrow} S \not\subseteq Q_t$ for some $t \in T$. Then $f_\psi \not\subseteq \overline{Q}_{(s,t)}$ and $S \not\subseteq Q_s$ for some $s \in S$. Hence, there exists a point $s' \in S$ such that $\overline{P}_{(s',\psi(s'))} \not\subseteq \overline{Q}_{(s,t)}$ and so $P_{\psi(s)} \not\subseteq Q_t$. Since $P_t \subseteq P_{\psi(s)}$, then $t \in \psi(S)$, that is $f_\psi^{\rightarrow} S \subseteq \psi(S)$. Now assume that $\psi(S) \not\subseteq f_\psi^{\rightarrow} S$. Choose a point $t \in T$ where $t \in \psi(S)$ and $t \notin f_\psi^{\rightarrow} S$. Then there exists a point $t' \in T$ such that $P_t \not\subseteq Q_{t'}$ and for all $s \in S$,

$$f_\psi \not\subseteq \overline{Q}_{(s,t')} \Rightarrow S \subseteq Q_s.$$

Since there is a point $s' \in S$ with $\psi(s') = t$, then $P_{\psi(s')} \not\subseteq Q_{t'}$ and so $\overline{P}_{(s',\psi(s')} \not\subseteq \overline{Q}_{(s',t')}$. Therefore, $f_\psi \not\subseteq \overline{Q}_{(s',t')}$ and this gives $S \subseteq Q_{s'}$. Since $(S, \mathcal{S})$ is plain, then $P_{s'} \not\subseteq Q_{s'}$ is a contradiction. As a result, $\psi(S) \subseteq f_\psi^{\rightarrow} S$ and this complete the proof of (i) .

(ii) Let $P_t \not\subseteq Q_{t'}$ and $t, t' \in \psi(S)$. Let us choose a point $w \in \psi(S)$ where $P_t \not\subseteq Q_w$ and $P_w \not\subseteq Q_{t'}$. Take $s \in S$ with $\psi(s) = w$. Then $P_{\psi(s)} \not\subseteq Q_{t'} \Rightarrow \overline{P}_{(s,\psi(s))} \not\subseteq \overline{Q}_{(s,t')} \Rightarrow f_\psi \not\subseteq \overline{Q}_{(s,t')} \Rightarrow f_\psi \cap (S \times \psi(S)) \not\subseteq \overline{Q}_{(s,t')} \Rightarrow (f_\psi)_{S\times\psi(S)} \not\subseteq \overline{Q}_{(s,t')}$.
Further, $P_t \not\subseteq Q_{\psi(s)} \Rightarrow P_{(s,t)} \not\subseteq Q_{(s,\psi(s))} \Rightarrow P_{(s,t)} \not\subseteq F_\psi \Rightarrow P_{(s,t)} \not\subseteq F_\psi \cap (S \times B) \Rightarrow P_{(s,t)} \not\subseteq (F_\psi)_{(S\times\psi(S)}$.

Definition 2.2 *Let* $(S, \mathcal{S}), (S_\alpha, \mathcal{S}_\alpha) \in$ *Ob* **fPTex** *and* $\varphi_\alpha \in$ *Mor* **fPTex** (S, S_α) *for* $\alpha \in J$. *Then the function* $\varepsilon : S \to \prod_{\alpha\in J} S_\alpha$ *defined by*

$$\varepsilon(s) = (\varphi_\alpha(s))_{\alpha\in J}$$

is called an evaluation function.

Theorem 2.3 $\varepsilon \in$ *Mor* **fPTex**.

Proof Clearly for each $\alpha \in J$, $\rho_\alpha \circ \varepsilon = \varphi_\alpha$ where $\rho_\alpha : \prod_{a\in J} S_\alpha \to S_\alpha$ is the projection function. Further, by [5, Lemma 3.9] we have $\rho_\alpha \in$ Mor **fPTex**. Now we show that ε satisfies (a). Let $P_s \not\subseteq Q_{s'}$ where $s, s' \in S$. Then $P_{\varphi_\alpha(s)} \not\subseteq Q_{\varphi_\alpha(s')}$ for all $\alpha \in J$ and so $P_{(\rho_\alpha\circ\varepsilon)(s)} \not\subseteq Q_{(\rho_\alpha\circ\varepsilon)(s')}$, that is $P_{\rho_\alpha(\varepsilon(s))} \not\subseteq Q_{\rho_\alpha(\varepsilon)(s')}$ for all $\alpha \in J$ and therefore, $P_{\varepsilon(s)} \not\subseteq Q_{\varepsilon(s')}$.

By Lemma 1.2 and Theorem 2.1, we have the following result:

Corollary 2.4 *$(e_\varepsilon, E_\varepsilon)$ is a difunction where*

$$e_\varepsilon = \bigvee\{\overline{P}_{(s,\varepsilon(s))} \mid s \in S\} \text{ and } E_\varepsilon = \bigcap\{\overline{Q}_{(s,\varepsilon(s))} \mid s \in S^\flat\}$$

and if $\varepsilon(S) \in \bigotimes_{\alpha\in J} \mathcal{S}_\alpha$, then $((e_\varepsilon)_{S\times\varepsilon(S)}, (E_\varepsilon)_{S\times\varepsilon(S)})$ is surjective.

Theorem 2.5 *Let ε be the point evaluation function induced by $\mathbf{BC_{fPDitop}}(S,\ S_\alpha) = \{\psi_\alpha \mid \alpha \in A\}$. Then $(e_\varepsilon, E_\varepsilon)$ is the evaluation difunction induced by the family $\mathbf{BC}(S,\ S_\alpha) = \{(f_{\psi_\alpha}, F_{\psi_\alpha}) \mid \alpha \in J\}$.*

Proof We must show that $\pi_\alpha \circ e_\varepsilon = f_{\psi_\alpha}$ and $\Pi_\alpha \circ E_\varepsilon = F_{\psi_\alpha}$. Let $\pi_\alpha \circ e_\varepsilon \nsubseteq \overline{Q}_{(k,s_\alpha)}$ for some $k \in S$ and $s_\alpha \in S_\alpha$. Then there exists $r \in S$ and $w_\alpha \in S_\alpha$ such that $\overline{P}_{(r,w_\alpha)} \nsubseteq \overline{Q}_{(k,s_\alpha)}$ where $e_\varepsilon \nsubseteq \overline{Q}_{(r,\ (u_\alpha)_{\alpha\in J})}$ and $\pi_\alpha \nsubseteq \overline{Q}_{((u_\alpha)_{\alpha\in J},\ w_\alpha)}$. However, $k = r$ and $P_{w_\alpha} \nsubseteq Q_{s_\alpha}$ and so $e_\varepsilon \nsubseteq \overline{Q}_{(k,\ (u_\alpha)_{\alpha\in J})}$. Since $\pi_\alpha \nsubseteq \overline{Q}_{((u_\alpha)_{\alpha\in J},\ w_\alpha)}$, then $\overline{P}_{((v_\alpha)_{\alpha\in J},\ v_\alpha)} \nsubseteq \overline{Q}_{(u_\alpha)_{\alpha\in J},\ w_\alpha)}$ for some $(v_\alpha)_{\alpha\in J} \in \prod_{\alpha\in J} S_\alpha$. Therefore, $(v_\alpha)_{\alpha\in J} = (u_\alpha)_{\alpha\in J}$ and $P_{u_\alpha} \nsubseteq Q_{w_\alpha}$. By definition of e_ε, we may write $\overline{P}_{(s',\varepsilon(s'))} \nsubseteq \overline{Q}_{(k,\ (u_\alpha)_{\alpha\in J})}$ for some $s' \in S$. Then we have $P_{\varepsilon(k)} \nsubseteq Q_{(u_\alpha)_{\alpha\in J}}$, that is $P_{(\psi_\alpha(k))_{\alpha\in J}} \nsubseteq Q_{(u_\alpha)_{\alpha\in J}}$ and by [5, Corollary 1.4] $P_{\psi_\alpha(k)} \nsubseteq Q_{u_\alpha}$ for all $\alpha \in J$. Since $P_{w_\alpha} \nsubseteq Q_{s_\alpha}$ and $P_{u_\alpha} \nsubseteq Q_{w_\alpha}$ then $Q_{s_\alpha} \subseteq Q_{u_\alpha}$. This gives that $P_{\psi_\alpha(k)} \nsubseteq Q_{s_\alpha}$, that is $f_{\psi_\alpha} \nsubseteq \overline{Q}_{(k,s_\alpha)}$. As a result $\pi_\alpha \circ e_\varepsilon \subseteq f_{\psi_\alpha}$ and by [5, Proposition 2.27] we have $\Pi_\alpha \circ E_\varepsilon \subseteq F_{\psi_\alpha}$.

Now we show that $F_{\psi_\alpha} \subseteq \Pi_\alpha \circ E_\varepsilon$. Let $F_{\psi_\alpha} \nsubseteq \overline{Q}_{(k,s_\alpha)}$ and $\overline{P}_{(k,s_\alpha)} \nsubseteq \Pi_\alpha \circ E_\varepsilon$ for some $k \in S, s_\alpha \in S_\alpha$. By the definition of composition, $\overline{P}_{(k,s_\alpha)} \nsubseteq \overline{Q}_{(s,u_\alpha)}$ and $\overline{P}_{(s,(t_\alpha)_{\alpha\in J})} \nsubseteq E_\epsilon$, $\overline{P}_{((t_\alpha)_{\alpha\in J},u_\alpha)} \nsubseteq \Pi_\alpha$ where $s \in S, u_\alpha \in S_\alpha, (t_\alpha)_{\alpha\in J} \in \prod_{\alpha\in J} S_\alpha$. However, $s = k$ and $P_{s_\alpha} \nsubseteq Q_{u_\alpha}$ and so $\overline{P}_{(k,(t_\alpha)_{\alpha\in J})} \nsubseteq E_\varepsilon$. By the definition of Π_α, we may write $\overline{P}_{((t_\alpha)_{\alpha\in J},u_\alpha)} \nsubseteq \overline{Q}_{((v_\alpha)_{\alpha\in J},v_\alpha)}$ for some $(v_\alpha)_{\alpha\in J} \in \prod_{\alpha\in J} S_\alpha$. Therefore, $(t_\alpha)_{\alpha\in J} = (v_\alpha)_{\alpha\in J}$ and $P_{u_\alpha} \nsubseteq Q_{v_\alpha}$. By the definition of E_ϵ, we may write that $\overline{P}_{(k,(t_\alpha)_{\alpha\in J})} \nsubseteq \overline{Q}_{(s',\epsilon(s'))}$ for some $s' \in S$. Then we have $P_{(t_\alpha)_{\alpha\in J}} \nsubseteq Q_{\epsilon(k)}$, that is $P_{(t_\alpha)_{\alpha\in J}} \nsubseteq Q_{(\psi_\alpha(k))_{\alpha\in J}}$ and by [5, Corollary 1.4] $P_{t_\alpha} \nsubseteq Q_{\psi_\alpha(k)}$ for all $\alpha \in J$. Sice $P_{s_\alpha} \nsubseteq Q_{u_\alpha}$ and $P_{u_\alpha} \nsubseteq Q_{t_\alpha}$ then $P_{t_\alpha} \subseteq P_{s_\alpha}$. This gives that $P_{s_\alpha} \nsubseteq Q_{\psi_\alpha(k)}$, that is $\overline{P}_{(k,s_\alpha)} \nsubseteq F_{\psi_\alpha}$. But this is a conradiction. As a result $F_{\psi_\alpha} \subseteq \Pi_\alpha \circ E_\varepsilon$ and by [5, Proposition 2.27] we have $f_{\psi_\alpha} \subseteq \pi_\alpha \circ e_\varepsilon$.

Now consider the family $\mathbf{BC}(S,\ \mathbb{I}) = \{(f_\psi, F_\psi) \mid \psi \in \mathbf{BC_{fPDitop}}(S,\ \mathbb{I})\}$. Let $(e_\varepsilon, E_\varepsilon)$ be the evaluation difunction induced by $\mathbf{BC}(S,\ \mathbb{I})$.

Theorem 2.6 *Let $\varepsilon(S) \in \bigotimes_{\alpha\in J} \mathcal{I}_\alpha$ and $(S, \mathcal{S}, \tau, \kappa)$ be a T_0 and completely biregular in* **dfPDitop**. *Then there exists a dihomeomorphic embedding from S to the Tychonoff dicube. $[\varepsilon(S)]$ is called the Stone–Cěch compactification of S.*

Proof By Theorem 1.4, $(S, \mathcal{S}, \tau, \kappa)$ is also completely biregular in **fPDitop**. By Theorem 1.5, $(e_\varepsilon, E_\varepsilon)$ is injective and bicontinuous. Further, by Corollary 2.4, $((e_\varepsilon)_{(S\times B)}, (E_\varepsilon)_{(S\times B)})$ is surjective where $B = e_\varepsilon^{\to} S$. Now we show that it is open. Let $G \in \tau$ and $G \not\subseteq Q_s$. Since $\mathbf{BC}(S,\ \mathbb{I})$ separates q-sets and open sets, we have $f_\psi^{\to} P_s \subseteq]F_\psi^{\to} G[$ for some $\psi \in \mathbf{BC}_{\mathbf{fPDitop}}(S,\ \mathbb{I})$. Since the projection difunction (π_α, Π_α) is bicontinuous, then $\pi_\psi^{\leftarrow}]F_\psi^{\to} G[$ is open in S and

$$(e_\varepsilon)^{\to}_{(S\times B)} P_s = e_\varepsilon^{\to} P_s \subseteq (\pi_\psi^{\leftarrow} \circ \pi_\psi)(e_\varepsilon^{\to} P_s) = \pi_\psi^{\leftarrow} (\pi_\psi \circ e)^{\to} P_s = \pi_\psi^{\leftarrow} f_\psi^{\to} P_s \subseteq \pi_\psi^{\leftarrow}]F_\psi^{\to} G[.$$

Therefore, we find $(e_\varepsilon)^{\to}_{(S\times B)} G \subseteq \pi_\psi^{\leftarrow}]F_\psi^{\to} G[$. Further,

$$\pi_\psi^{\leftarrow}]F_\psi^{\to} G[\subseteq \pi_\psi^{\leftarrow} F_\psi^{\to} G = \pi_\psi^{\leftarrow} (\Pi_\psi \circ E)^{\to} G = (\pi_\psi^{\leftarrow} \circ \Pi_\psi)^{\to} (E_\varepsilon^{\to} G) \subseteq E_\varepsilon^{\to} G = (E_\varepsilon)^{\to}_{(S\times B)} G$$

As a result,

$$(e_\varepsilon)^{\to}_{(S\times B)} G \subseteq \pi_\psi^{\leftarrow}]F_\psi^{\to} G[\subseteq (E_\varepsilon)^{\to}_{(S\times B)} G$$

However, since $((e_\varepsilon)^{\to}_{(S\times B)}, (E_\varepsilon)_{(S\times B)})$ is bijective, by [5, Corollary 2.33.(1)(i)], we find

$$(e_\varepsilon)^{\to}_{(S\times B)} G = \pi_\psi^{\leftarrow}]F_\psi^{\to} G[= (E_\varepsilon)^{\to}_{(S\times B)} G$$

Now let $P_s \not\subseteq K$ and $K \in \kappa$. Since $\mathbf{BC}(S,\ \mathbb{I})$ separates p-sets and closed sets, we have $F_\psi^{\to} Q_s \supseteq [f_\psi^{\to} K]$ for some $\psi \in \mathbf{BC}_{\mathbf{fPDitop}}(S,\ \mathbb{I})$. In this case,

$$E_\varepsilon^{\to} Q_s = (\Pi_\psi^{\leftarrow} \circ \Pi_\psi)^{\to} E^{\to} Q_s = \Pi_\psi^{\leftarrow} F_\psi^{\to} Q_s \supseteq \Pi_\psi^{\leftarrow} [f_\psi^{\to} K],$$

that is

$$(E_\varepsilon)^{\to}_{(S\times B)} K = E^{\to} K = E^{\to} \bigcap \{Q_s \mid P_s \not\subseteq K\} = \bigcap \{E^{\to} Q_s \mid P_s \not\subseteq K\} \supseteq \Pi_\psi^{\leftarrow} [f_\psi^{\to} K].$$

Further,

$$(e_\varepsilon)^{\to}_{(S\times B)} K = e_\varepsilon^{\to} K \subseteq (\pi_\psi^{\leftarrow} \circ \pi_\psi)^{\to} (e_\varepsilon^{\to} K) \subseteq \pi_\psi^{\leftarrow} (\pi_\psi \circ e_\varepsilon) K = \Pi_\psi^{\leftarrow} f_\psi^{\to} K \subseteq \Pi_\psi^{\leftarrow} [f_\psi^{\to} K].$$

As a result, we find

$$e_\varepsilon^{\to} K \subseteq \Pi_\psi^{\leftarrow} [f_\psi^{\to} K] \subseteq E^{\to} K.$$

Since $((e_\varepsilon)^{\to}_{(S\times B)}, (E_\varepsilon)_{(S\times e_\varepsilon^{\to} S)})$ is bijective, by [5, Corollary 2.33.(1)(i)], we find

$$(e_\varepsilon)^{\to}_{(S\times B)} K = \Pi_\psi^{\leftarrow} [f_\psi^{\to} K] = (E_\varepsilon)^{\to}_{(S\times B)} K.$$

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