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Some Properties of Real Maps

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Summary. The main goal of the paper is to show logical equivalence of the two definitions of the *open subset*: one from [3] and the other from [21]. This has been used to show that the other two definitions are equivalent: the continuity of the map as in [19] and in [20]. We used this to show that continuous and one-to-one maps are monotone (see theorems 16 and 17 for details).

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The articles [22], [24], [1], [23], [14], [25], [26], [5], [6], [20], [11], [4], [21], [7], [17], [15], [18], [12], [19], [9], [8], [10], [16], [3], [2], and [13] provide the notation and terminology for this paper.

1. Preliminaries

One can prove the following four propositions:

(1) Let n be a natural number, p, q be points of $\mathcal{E}^n_{\rm T}$, and P be a subset of $\mathcal{E}^n_{\rm T}$. If P is an arc from p to q, then P is compact.

(2) For every real number r holds $0 \leq r$ and $r \leq 1$ iff $r \in$ the carrier of $\mathbb{I}$.

(3) Let n be a natural number, p_1, p_2 be points of $\mathcal{E}^n_{\rm T}$, and r_1, r_2 be real numbers. If $(1-r_1) \cdot p_1 + r_1 \cdot p_2 = (1-r_2) \cdot p_1 + r_2 \cdot p_2$, then $r_1 = r_2$ or $p_1 = p_2$.

(4) Let n be a natural number and p_1, p_2 be points of $\mathcal{E}^n_{\rm T}$. Suppose $p_1 \neq p_2$. Then there exists a map f from $\mathbb{I}$ into $(\mathcal{E}^n_{\rm T}) \restriction \mathcal{L}(p_1, p_2)$ such that for every real number x such that $x \in [0,1]$ holds $f(x) = (1-x) \cdot p_1 + x \cdot p_2$ and f is a homeomorphism and $f(0) = p_1$ and $f(1) = p_2$.

Let n be a natural number. Note that $\mathcal{E}^n_{\rm T}$ is arcwise connected.

Let n be a natural number. One can check that there exists a subspace of $\mathcal{E}^n_{\rm T}$ which is compact and non empty.

One can prove the following proposition

(5) Let a, b be points of $\mathcal{E}^2_{\rm T}$, f be a path from a to b, P be a non empty compact subspace of $\mathcal{E}^2_{\rm T}$, and g be a map from $\mathbb{I}$ into P. If f is one-to-one and $g = f$ and $\Omega_P = \operatorname{rng} f$, then g is a homeomorphism.

2. EQUIVALENCE OF ANALYTICAL AND TOPOLOGICAL DEFINITIONS OF CONTINUITY

We now state a number of propositions:

(6) Let X be a subset of $\mathbb{R}$. Then $X \in$ the open set family of the metric space of real numbers if and only if X is open.

(7) Let f be a map from $\mathbb{R}^{\mathbf{1}}$ into $\mathbb{R}^{\mathbf{1}}$, x be a point of $\mathbb{R}^{\mathbf{1}}$, g be a partial function from $\mathbb{R}$ to $\mathbb{R}$, and x_1 be a real number. If f is continuous at x and $f = g$ and $x = x_1$, then g is continuous in x_1.

(8) Let f be a continuous map from $\mathbb{R}^{\mathbf{1}}$ into $\mathbb{R}^{\mathbf{1}}$ and g be a partial function from $\mathbb{R}$ to $\mathbb{R}$. If $f = g$, then g is continuous on $\mathbb{R}$.

(9) Let f be a continuous one-to-one map from $\mathbb{R}^{\mathbf{1}}$ into $\mathbb{R}^{\mathbf{1}}$. Then

(i) for all points x, y of $\mathbb{I}$ and for all real numbers p, q, f_1, f_2 such that $x = p$ and $y = q$ and $p < q$ and $f_1 = f(x)$ and $f_2 = f(y)$ holds $f_1 < f_2$, or

(ii) for all points x, y of $\mathbb{I}$ and for all real numbers p, q, f_1, f_2 such that $x = p$ and $y = q$ and $p < q$ and $f_1 = f(x)$ and $f_2 = f(y)$ holds $f_1 > f_2$.

(10) Let r, g_1, a, b be real numbers and x be an element of $[a, b]_{\rm M}$. If $a \leq b$ and $x = r$ and $g_1 > 0$ and $]r - g_1, r + g_1[\subseteq [a, b]$, then $]r - g_1, r + g_1[= \mathrm{Ball}(x, g_1)$.

(11) Let a, b be real numbers and X be a subset of $\mathbb{R}$. Suppose $a < b$ and $a \notin X$ and $b \notin X$. If $X \in$ the open set family of $[a, b]_{\rm M}$, then X is open.

(12) For every open subset X of $\mathbb{R}$ and for all real numbers a, b such that $X \subseteq [a, b]$ holds $a \notin X$ and $b \notin X$.

(13) Let a, b be real numbers, X be a subset of $\mathbb{R}$, and V be a subset of $[a, b]_{\rm M}$. Suppose $a \leq b$ and $V = X$. If X is open, then $V \in$ the open set family of $[a, b]_{\rm M}$.

(14) Let a, b, c, d, x_1 be real numbers, f be a map from $[a, b]_{\rm T}$ into $[c, d]_{\rm T}$, x be a point of $[a, b]_{\rm T}$, and g be a partial function from $\mathbb{R}$ to $\mathbb{R}$. Suppose $a < b$ and $c < d$ and f is continuous at x and $f(a) = c$ and $f(b) = d$ and f is one-to-one and $f = g$ and $x = x_1$. Then $g{\restriction}[a, b]$ is continuous in x_1.

(15) Let a, b, c, d be real numbers, f be a map from $[a, b]_{\rm T}$ into $[c, d]_{\rm T}$, and g be a partial function from $\mathbb{R}$ to $\mathbb{R}$. Suppose f is continuous and one-to-one and $a < b$ and $c < d$ and $f = g$ and $f(a) = c$ and $f(b) = d$. Then g is continuous on $[a, b]$.

3. ON THE MONOTONICITY OF CONTINUOUS MAPS

Next we state several propositions:

(16) Let a, b, c, d be real numbers and f be a map from $[a, b]_{\rm T}$ into $[c, d]_{\rm T}$. Suppose $a < b$ and $c < d$ and f is continuous and one-to-one and $f(a) = c$ and $f(b) = d$. Let x, y be points of $[a, b]_{\rm T}$ and p, q, f_1, f_2 be real numbers. If $x = p$ and $y = q$ and $p < q$ and $f_1 = f(x)$ and $f_2 = f(y)$, then $f_1 < f_2$.

(17) Let f be a continuous one-to-one map from $\mathbb{I}$ into $\mathbb{I}$. Suppose $f(0) = 0$ and $f(1) = 1$. Let x, y be points of $\mathbb{I}$ and p, q, f_1, f_2 be real numbers. If $x = p$ and $y = q$ and $p < q$ and $f_1 = f(x)$ and $f_2 = f(y)$, then $f_1 < f_2$.

(18) Let a, b, c, d be real numbers, f be a map from $[a, b]_{\rm T}$ into $[c, d]_{\rm T}$, P be a non empty subset of $[a, b]_{\rm T}$, and P_1, Q_1 be subsets of $\mathbb{R}^{\mathbf{1}}$. Suppose $a < b$ and $c < d$ and $P_1 = P$ and f is continuous and one-to-one and P_1 is compact and $f(a) = c$ and $f(b) = d$ and $f^{\circ}P = Q_1$. Then $f(\inf(\Omega_{(P_1)})) = \inf(\Omega_{(Q_1)})$.

(19) Let a, b, c, d be real numbers, f be a map from $[a,b]_{\rm T}$ into $[c,d]_{\rm T}$, P, Q be non empty subsets of $[a,b]_{\rm T}$, and P_1, Q_1 be subsets of $\mathbb{R}^{\mathbf{1}}$. Suppose $a < b$ and $c < d$ and $P_1 = P$ and $Q_1 = Q$ and f is continuous and one-to-one and P_1 is compact and $f(a) = c$ and $f(b) = d$ and $f^{\circ}P = Q$. Then $f(\sup(\Omega_{(P_1)})) = \sup(\Omega_{(Q_1)})$.

(20) For all real numbers a, b such that $a \leq b$ holds $\inf[a,b] = a$ and $\sup[a,b] = b$.

(21) Let a, b, c, d, e, f, g, h be real numbers and F be a map from $[a,b]_{\rm T}$ into $[c,d]_{\rm T}$. Suppose $a < b$ and $c < d$ and $e < f$ and $a \leq e$ and $f \leq b$ and F is a homeomorphism and $F(a) = c$ and $F(b) = d$ and $g = F(e)$ and $h = F(f)$. Then $F^{\circ}[e,f] = [g,h]$.

(22) Let P, Q be subsets of $\mathcal{E}^2_{\rm T}$ and p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose P meets Q and $P \cap Q$ is closed and P is an arc from p_1 to p_2. Then there exists a point E_1 of $\mathcal{E}^2_{\rm T}$ such that

(i) $E_1 \in P \cap Q$, and

(ii) there exists a map g from $\mathbb{I}$ into $(\mathcal{E}^2_{\rm T}) \restriction P$ and there exists a real number s_2 such that g is a homeomorphism and $g(0) = p_1$ and $g(1) = p_2$ and $g(s_2) = E_1$ and $0 \leq s_2$ and $s_2 \leq 1$ and for every real number t such that $0 \leq t$ and $t < s_2$ holds $g(t) \notin Q$.

(23) Let P, Q be subsets of $\mathcal{E}^2_{\rm T}$ and p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose P meets Q and $P \cap Q$ is closed and P is an arc from p_1 to p_2. Then there exists a point E_1 of $\mathcal{E}^2_{\rm T}$ such that

(i) $E_1 \in P \cap Q$, and

(ii) there exists a map g from $\mathbb{I}$ into $(\mathcal{E}^2_{\rm T}) \restriction P$ and there exists a real number s_2 such that g is a homeomorphism and $g(0) = p_1$ and $g(1) = p_2$ and $g(s_2) = E_1$ and $0 \leq s_2$ and $s_2 \leq 1$ and for every real number t such that $1 \geq t$ and $t > s_2$ holds $g(t) \notin Q$.

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