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Fan Homeomorphisms in the Plane

Yatsuka Nakamura
Shinshu University
Nagano

Summary. We will introduce four homeomorphisms (Fan morphisms) which give spoke-like distortion to the plane. They do not change the norms of vectors and preserve halfplanes invariant. These morphisms are used to regulate placement of points on the circle.

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

1. Preliminaries

In this paper x, a denote real numbers and p, q denote points of $\mathcal{E}^2_{\rm T}$.

We now state a number of propositions:

(2)[1] If $a \geq 0$ and $(x-a)\cdot(x+a) < 0$, then $-a < x$ and $x < a$.

(3) For every real number s_1 such that $-1 < s_1$ and $s_1 < 1$ holds $1+s_1 > 0$ and $1-s_1 > 0$.

(4) For every real number a such that $a^{\mathbf{2}} \leq 1$ holds $-1 \leq a$ and $a \leq 1$.

(5) For every real number a such that $a^{\mathbf{2}} < 1$ holds $-1 < a$ and $a < 1$.

(6) Let X be a non empty topological structure, g be a map from X into $\mathbb{R}^{\mathbf{1}}$, B be a subset of X, and a be a real number. If g is continuous and $B = \{p; p$ ranges over points of X: $\pi_p g > a\}$, then B is open.

(7) Let X be a non empty topological structure, g be a map from X into $\mathbb{R}^{\mathbf{1}}$, B be a subset of X, and a be a real number. If g is continuous and $B = \{p; p$ ranges over points of X: $\pi_p g < a\}$, then B is open.

(8) Let f be a map from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$. Suppose that

(i) f is continuous and one-to-one,

(ii) $\operatorname{rng} f = \Omega_{\mathcal{E}^2_{\rm T}}$, and

(iii) for every point p_2 of $\mathcal{E}^2_{\rm T}$ there exists a non empty compact subset K of $\mathcal{E}^2_{\rm T}$ such that $K = f^\circ K$ and there exists a subset V_2 of $\mathcal{E}^2_{\rm T}$ such that $p_2 \in V_2$ and V_2 is open and $V_2 \subseteq K$ and $f(p_2) \in V_2$.

Then f is a homeomorphism.

[1] The proposition (1) has been removed.

(9) Let X be a non empty topological space, f_1, f_2 be maps from X into $\mathbb{R}^{\mathbf{1}}$, and a, b be real numbers. Suppose f_1 is continuous and f_2 is continuous and $b \neq 0$ and for every point q of X holds $f_2(q) \neq 0$. Then there exists a map g from X into $\mathbb{R}^{\mathbf{1}}$ such that

(i) for every point p of X and for all real numbers r_1, r_2 such that $f_1(p) = r_1$ and $f_2(p) = r_2$ holds $g(p) = \frac{\frac{r_1}{r_2} - a}{b}$, and

(ii) g is continuous.

(10) Let X be a non empty topological space, f_1, f_2 be maps from X into $\mathbb{R}^{\mathbf{1}}$, and a, b be real numbers. Suppose f_1 is continuous and f_2 is continuous and $b \neq 0$ and for every point q of X holds $f_2(q) \neq 0$. Then there exists a map g from X into $\mathbb{R}^{\mathbf{1}}$ such that

(i) for every point p of X and for all real numbers r_1, r_2 such that $f_1(p) = r_1$ and $f_2(p) = r_2$ holds $g(p) = r_2 \cdot \frac{\frac{r_1}{r_2} - a}{b}$, and

(ii) g is continuous.

(11) Let X be a non empty topological space and f_1 be a map from X into $\mathbb{R}^{\mathbf{1}}$. Suppose f_1 is continuous. Then there exists a map g from X into $\mathbb{R}^{\mathbf{1}}$ such that for every point p of X and for every real number r_1 such that $f_1(p) = r_1$ holds $g(p) = {r_1}^{\mathbf{2}}$ and g is continuous.

(12) Let X be a non empty topological space and f_1 be a map from X into $\mathbb{R}^{\mathbf{1}}$. Suppose f_1 is continuous. Then there exists a map g from X into $\mathbb{R}^{\mathbf{1}}$ such that for every point p of X and for every real number r_1 such that $f_1(p) = r_1$ holds $g(p) = |r_1|$ and g is continuous.

(13) Let X be a non empty topological space and f_1 be a map from X into $\mathbb{R}^{\mathbf{1}}$. Suppose f_1 is continuous. Then there exists a map g from X into $\mathbb{R}^{\mathbf{1}}$ such that for every point p of X and for every real number r_1 such that $f_1(p) = r_1$ holds $g(p) = -r_1$ and g is continuous.

(14) Let X be a non empty topological space, f_1, f_2 be maps from X into $\mathbb{R}^{\mathbf{1}}$, and a, b be real numbers. Suppose f_1 is continuous and f_2 is continuous and $b \neq 0$ and for every point q of X holds $f_2(q) \neq 0$. Then there exists a map g from X into $\mathbb{R}^{\mathbf{1}}$ such that

(i) for every point p of X and for all real numbers r_1, r_2 such that $f_1(p) = r_1$ and $f_2(p) = r_2$ holds $g(p) = r_2 \cdot -\sqrt{|1 - (\frac{\frac{r_1}{r_2} - a}{b})^{\mathbf{2}}|}$, and

(ii) g is continuous.

(15) Let X be a non empty topological space, f_1, f_2 be maps from X into $\mathbb{R}^{\mathbf{1}}$, and a, b be real numbers. Suppose f_1 is continuous and f_2 is continuous and $b \neq 0$ and for every point q of X holds $f_2(q) \neq 0$. Then there exists a map g from X into $\mathbb{R}^{\mathbf{1}}$ such that

(i) for every point p of X and for all real numbers r_1, r_2 such that $f_1(p) = r_1$ and $f_2(p) = r_2$ holds $g(p) = r_2 \cdot \sqrt{|1 - (\frac{\frac{r_1}{r_2} - a}{b})^{\mathbf{2}}|}$, and

(ii) g is continuous.

Let n be a natural number. The functor $n\,\mathrm{NormF}$ yields a function from the carrier of $\mathcal{E}^n_{\mathrm{T}}$ into the carrier of $\mathbb{R}^{\mathbf{1}}$ and is defined as follows:

(Def. 1) For every point q of $\mathcal{E}^n_{\mathrm{T}}$ holds $n\,\mathrm{NormF}(q) = |q|$.

The following propositions are true:

(16) For every natural number n holds $\mathrm{dom}(n\,\mathrm{NormF}) =$ the carrier of $\mathcal{E}^n_{\mathrm{T}}$ and $\mathrm{dom}(n\,\mathrm{NormF}) = \mathcal{R}^n$.

(19)[2] For every natural number n and for every map f from $\mathcal{E}^n_{\mathrm{T}}$ into $\mathbb{R}^{\mathbf{1}}$ such that $f = n\,\mathrm{NormF}$ holds f is continuous.

[2] The propositions (17) and (18) have been removed.

(20) Let n be a natural number, K_0 be a subset of $\mathcal{E}^n_{\mathrm{T}}$, and f be a map from $(\mathcal{E}^n_{\mathrm{T}})\restriction K_0$ into $\mathbb{R}^{\mathbf{1}}$. If for every point p of $(\mathcal{E}^n_{\mathrm{T}})\restriction K_0$ holds $f(p) = n\mathrm{NormF}(p)$, then f is continuous.

(21) Let n be a natural number, p be a point of $\mathcal{E}^n$, r be a real number, and B be a subset of $\mathcal{E}^n_{\mathrm{T}}$. If $B = \overline{\mathrm{Ball}}(p,r)$, then B is Bounded and closed.

(22) For every point p of $\mathcal{E}^2$ and for every real number r and for every subset B of $\mathcal{E}^2_{\mathrm{T}}$ such that $B = \overline{\mathrm{Ball}}(p,r)$ holds B is compact.

2. Fan Morphism for West

Let s be a real number and let q be a point of $\mathcal{E}^2_{\mathrm{T}}$. The functor $\mathrm{FanW}(s,q)$ yields a point of $\mathcal{E}^2_{\mathrm{T}}$ and is defined by:

(Def. 2) $$\mathrm{FanW}(s,q) = \begin{cases} |q| \cdot [-\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s}{1-s})^{\mathbf{2}}}, \frac{\frac{q_{\mathbf{2}}}{|q|}-s}{1-s}], \text{ if } \frac{q_{\mathbf{2}}}{|q|} \geq s \text{ and } q_{\mathbf{1}} < 0, \\ |q| \cdot [-\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s}{1+s})^{\mathbf{2}}}, \frac{\frac{q_{\mathbf{2}}}{|q|}-s}{1+s}], \text{ if } \frac{q_{\mathbf{2}}}{|q|} < s \text{ and } q_{\mathbf{1}} < 0, \\ q, \text{ otherwise.} \end{cases}$$

Let s be a real number. The functor s-FanMorphW yields a function from the carrier of $\mathcal{E}^2_{\mathrm{T}}$ into the carrier of $\mathcal{E}^2_{\mathrm{T}}$ and is defined by:

(Def. 3) For every point q of $\mathcal{E}^2_{\mathrm{T}}$ holds s-FanMorphW$(q) = \mathrm{FanW}(s,q)$.

The following propositions are true:

(23) Let s_1 be a real number. Then

(i) if $\frac{q_{\mathbf{2}}}{|q|} \geq s_1$ and $q_{\mathbf{1}} < 0$, then s_1-FanMorphW$(q) = [|q| \cdot -\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1-s_1})^{\mathbf{2}}}, |q| \cdot \frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1-s_1}]$, and

(ii) if $q_{\mathbf{1}} \geq 0$, then s_1-FanMorphW$(q) = q$.

(24) For every real number s_1 such that $\frac{q_{\mathbf{2}}}{|q|} \leq s_1$ and $q_{\mathbf{1}} < 0$ holds s_1-FanMorphW$(q) = [|q| \cdot -\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1+s_1})^{\mathbf{2}}}, |q| \cdot \frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1+s_1}]$.

(25) Let s_1 be a real number such that $-1 < s_1$ and $s_1 < 1$. Then

(i) if $\frac{q_{\mathbf{2}}}{|q|} \geq s_1$ and $q_{\mathbf{1}} \leq 0$ and $q \neq 0_{\mathcal{E}^2_{\mathrm{T}}}$, then s_1-FanMorphW$(q) = [|q| \cdot -\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1-s_1})^{\mathbf{2}}}, |q| \cdot \frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1-s_1}]$, and

(ii) if $\frac{q_{\mathbf{2}}}{|q|} \leq s_1$ and $q_{\mathbf{1}} \leq 0$ and $q \neq 0_{\mathcal{E}^2_{\mathrm{T}}}$, then s_1-FanMorphW$(q) = [|q| \cdot -\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1+s_1})^{\mathbf{2}}}, |q| \cdot \frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1+s_1}]$.

(26) Let s_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\mathrm{T}}$, and f be a map from $(\mathcal{E}^2_{\mathrm{T}})\restriction K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < s_1$,

(ii) $s_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\mathrm{T}}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\mathrm{T}})\restriction K_1$ holds $f(p) = |p| \cdot \frac{\frac{p_{\mathbf{2}}}{|p|}-s_1}{1-s_1}$, and

(iv) for every point q of $\mathcal{E}^2_{\mathrm{T}}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\mathrm{T}})\restriction K_1$ holds $q_{\mathbf{1}} \leq 0$ and $q \neq 0_{\mathcal{E}^2_{\mathrm{T}}}$.

Then f is continuous.

(27) Let s_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < s_1$,

(ii) $s_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot \frac{\frac{p_{\mathbf{2}}}{|p|} - s_1}{1+s_1}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\mathbf{1}} \leq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(28) Let s_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < s_1$,

(ii) $s_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot -\sqrt{1 - (\frac{\frac{p_{\mathbf{2}}}{|p|} - s_1}{1-s_1})^{\mathbf{2}}}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\mathbf{1}} \leq 0$ and $\frac{q_{\mathbf{2}}}{|q|} \geq s_1$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(29) Let s_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < s_1$,

(ii) $s_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot -\sqrt{1 - (\frac{\frac{p_{\mathbf{2}}}{|p|} - s_1}{1+s_1})^{\mathbf{2}}}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\mathbf{1}} \leq 0$ and $\frac{q_{\mathbf{2}}}{|q|} \leq s_1$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(30) Let s_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphW $\restriction K_0$ and $B_0 = \{q; q$ ranges over points of $\mathcal{E}^2_{\rm T}$: $q_{\mathbf{1}} \leq 0 \land q \neq 0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : \frac{p_{\mathbf{2}}}{|p|} \geq s_1 \land p_{\mathbf{1}} \leq 0 \land p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(31) Let s_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphW $\restriction K_0$ and $B_0 = \{q; q$ ranges over points of $\mathcal{E}^2_{\rm T}$: $q_{\mathbf{1}} \leq 0 \land q \neq 0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : \frac{p_{\mathbf{2}}}{|p|} \leq s_1 \land p_{\mathbf{1}} \leq 0 \land p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(32) For every real number s_1 and for every subset K_3 of $\mathcal{E}^2_{\rm T}$ such that $K_3 = \{p : p_{\mathbf{2}} \geq s_1 \cdot |p| \land p_{\mathbf{1}} \leq 0\}$ holds K_3 is closed.

(33) For every real number s_1 and for every subset K_3 of $\mathcal{E}^2_{\rm T}$ such that $K_3 = \{p : p_{\mathbf{2}} \leq s_1 \cdot |p| \land p_{\mathbf{1}} \leq 0\}$ holds K_3 is closed.

(34) Let s_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphW $\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{1}} \leq 0 \land p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(35) Let s_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphW$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{1}} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(36) Let B_0 be a subset of $\mathcal{E}^2_{\rm T}$ and K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{1}} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then K_0 is closed.

(37) Let s_1 be a real number, B_0 be a subset of $\mathcal{E}^2_{\rm T}$, K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction B_0\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphW$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{1}} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(38) Let B_0 be a subset of $\mathcal{E}^2_{\rm T}$ and K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{1}} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then K_0 is closed.

(39) Let s_1 be a real number, B_0 be a subset of $\mathcal{E}^2_{\rm T}$, K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction B_0\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphW$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{1}} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(40) For every real number s_1 and for every point p of $\mathcal{E}^2_{\rm T}$ holds $|s_1$-FanMorphW$(p)| = |p|$.

(41) For every real number s_1 and for all sets x, K_0 such that $-1 < s_1$ and $s_1 < 1$ and $x \in K_0$ and $K_0 = \{p : p_{\mathbf{1}} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$ holds s_1-FanMorphW$(x) \in K_0$.

(42) For every real number s_1 and for all sets x, K_0 such that $-1 < s_1$ and $s_1 < 1$ and $x \in K_0$ and $K_0 = \{p : p_{\mathbf{1}} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$ holds s_1-FanMorphW$(x) \in K_0$.

(43) Let s_1 be a real number and D be a non empty subset of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $D^{\rm c} = \{0_{\mathcal{E}^2_{\rm T}}\}$. Then there exists a map h from $(\mathcal{E}^2_{\rm T})\restriction D$ into $(\mathcal{E}^2_{\rm T})\restriction D$ such that $h = s_1$-FanMorphW$\restriction D$ and h is continuous.

(44) Let s_1 be a real number. Suppose $-1 < s_1$ and $s_1 < 1$. Then there exists a map h from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ such that $h = s_1$-FanMorphW and h is continuous.

(45) For every real number s_1 such that $-1 < s_1$ and $s_1 < 1$ holds s_1-FanMorphW is one-to-one.

(46) For every real number s_1 such that $-1 < s_1$ and $s_1 < 1$ holds s_1-FanMorphW is a map from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ and rng(s_1-FanMorphW) = the carrier of $\mathcal{E}^2_{\rm T}$.

(47) Let s_1 be a real number and p_2 be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$. Then there exists a non empty compact subset K of $\mathcal{E}^2_{\rm T}$ such that $K = s_1$-FanMorphW$^\circ K$ and there exists a subset V_2 of $\mathcal{E}^2_{\rm T}$ such that $p_2 \in V_2$ and V_2 is open and $V_2 \subseteq K$ and s_1-FanMorphW$(p_2) \in V_2$.

(48) Let s_1 be a real number. Suppose $-1 < s_1$ and $s_1 < 1$. Then there exists a map f from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ such that $f = s_1$-FanMorphW and f is a homeomorphism.

(49) Let s_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $q_{\mathbf{1}} < 0$ and $\frac{q_{\mathbf{2}}}{|q|} \geq s_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = s_1$-FanMorphW(q), then $p_{\mathbf{1}} < 0$ and $p_{\mathbf{2}} \geq 0$.

(50) Let s_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $q_{\mathbf{1}} < 0$ and $\frac{q_{\mathbf{2}}}{|q|} < s_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = s_1$-FanMorphW(q), then $p_{\mathbf{1}} < 0$ and $p_{\mathbf{2}} < 0$.

(51) Let s_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $(q_1)_{\mathbf{1}} < 0$ and $\frac{(q_1)_{\mathbf{2}}}{|q_1|} \geq s_1$ and $(q_2)_{\mathbf{1}} < 0$ and $\frac{(q_2)_{\mathbf{2}}}{|q_2|} \geq s_1$ and $\frac{(q_1)_{\mathbf{2}}}{|q_1|} < \frac{(q_2)_{\mathbf{2}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = s_1$-FanMorphW(q_1) and $p_2 = s_1$-FanMorphW(q_2), then $\frac{(p_1)_{\mathbf{2}}}{|p_1|} < \frac{(p_2)_{\mathbf{2}}}{|p_2|}$.

(52) Let s_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $(q_1)_{\mathbf{1}} < 0$ and $\frac{(q_1)_{\mathbf{2}}}{|q_1|} < s_1$ and $(q_2)_{\mathbf{1}} < 0$ and $\frac{(q_2)_{\mathbf{2}}}{|q_2|} < s_1$ and $\frac{(q_1)_{\mathbf{2}}}{|q_1|} < \frac{(q_2)_{\mathbf{2}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = s_1$-FanMorphW(q_1) and $p_2 = s_1$-FanMorphW(q_2), then $\frac{(p_1)_{\mathbf{2}}}{|p_1|} < \frac{(p_2)_{\mathbf{2}}}{|p_2|}$.

(53) Let s_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\mathrm{T}}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $(q_1)_{\mathbf{1}} < 0$ and $(q_2)_{\mathbf{1}} < 0$ and $\frac{(q_1)_{\mathbf{2}}}{|q_1|} < \frac{(q_2)_{\mathbf{2}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\mathrm{T}}$. If $p_1 = s_1$-FanMorphW(q_1) and $p_2 = s_1$-FanMorphW(q_2), then $\frac{(p_1)_{\mathbf{2}}}{|p_1|} < \frac{(p_2)_{\mathbf{2}}}{|p_2|}$.

(54) Let s_1 be a real number and q be a point of $\mathcal{E}^2_{\mathrm{T}}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $q_{\mathbf{1}} < 0$ and $\frac{q_{\mathbf{2}}}{|q|} = s_1$. Let p be a point of $\mathcal{E}^2_{\mathrm{T}}$. If $p = s_1$-FanMorphW(q), then $p_{\mathbf{1}} < 0$ and $p_{\mathbf{2}} = 0$.

(55) For every real number s_1 holds $0_{\mathcal{E}^2_{\mathrm{T}}} = s_1$-FanMorphW$(0_{\mathcal{E}^2_{\mathrm{T}}})$.

3. Fan Morphism for North

Let s be a real number and let q be a point of $\mathcal{E}^2_{\mathrm{T}}$. The functor FanN$(s,q)$ yielding a point of $\mathcal{E}^2_{\mathrm{T}}$ is defined by:

(Def. 4)
$$\mathrm{FanN}(s,q) = \begin{cases} |q| \cdot [\frac{\frac{q_{\mathbf{1}}}{|q|} - s}{1-s}, \sqrt{1 - (\frac{\frac{q_{\mathbf{1}}}{|q|} - s}{1-s})^{\mathbf{2}}}], & \text{if } \frac{q_{\mathbf{1}}}{|q|} \geq s \text{ and } q_{\mathbf{2}} > 0, \\ |q| \cdot [\frac{\frac{q_{\mathbf{1}}}{|q|} - s}{1+s}, \sqrt{1 - (\frac{\frac{q_{\mathbf{1}}}{|q|} - s}{1+s})^{\mathbf{2}}}], & \text{if } \frac{q_{\mathbf{1}}}{|q|} < s \text{ and } q_{\mathbf{2}} > 0, \\ q, & \text{otherwise.} \end{cases}$$

Let c be a real number. The functor c-FanMorphN yielding a function from the carrier of $\mathcal{E}^2_{\mathrm{T}}$ into the carrier of $\mathcal{E}^2_{\mathrm{T}}$ is defined as follows:

(Def. 5) For every point q of $\mathcal{E}^2_{\mathrm{T}}$ holds c-FanMorphN$(q) = \mathrm{FanN}(c,q)$.

The following propositions are true:

(56) Let c_1 be a real number. Then

(i) if $\frac{q_{\mathbf{1}}}{|q|} \geq c_1$ and $q_{\mathbf{2}} > 0$, then c_1-FanMorphN$(q) = [|q| \cdot \frac{\frac{q_{\mathbf{1}}}{|q|} - c_1}{1-c_1}, |q| \cdot \sqrt{1 - (\frac{\frac{q_{\mathbf{1}}}{|q|} - c_1}{1-c_1})^{\mathbf{2}}}]$, and

(ii) if $q_{\mathbf{2}} \leq 0$, then c_1-FanMorphN$(q) = q$.

(57) For every real number c_1 such that $\frac{q_{\mathbf{1}}}{|q|} \leq c_1$ and $q_{\mathbf{2}} > 0$ holds c_1-FanMorphN$(q) = [|q| \cdot \frac{\frac{q_{\mathbf{1}}}{|q|} - c_1}{1+c_1}, |q| \cdot \sqrt{1 - (\frac{\frac{q_{\mathbf{1}}}{|q|} - c_1}{1+c_1})^{\mathbf{2}}}]$.

(58) Let c_1 be a real number such that $-1 < c_1$ and $c_1 < 1$. Then

(i) if $\frac{q_{\mathbf{1}}}{|q|} \geq c_1$ and $q_{\mathbf{2}} \geq 0$ and $q \neq 0_{\mathcal{E}^2_{\mathrm{T}}}$, then c_1-FanMorphN$(q) = [|q| \cdot \frac{\frac{q_{\mathbf{1}}}{|q|} - c_1}{1-c_1}, |q| \cdot \sqrt{1 - (\frac{\frac{q_{\mathbf{1}}}{|q|} - c_1}{1-c_1})^{\mathbf{2}}}]$, and

(ii) if $\frac{q_{\mathbf{1}}}{|q|} \leq c_1$ and $q_{\mathbf{2}} \geq 0$ and $q \neq 0_{\mathcal{E}^2_{\mathrm{T}}}$, then c_1-FanMorphN$(q) = [|q| \cdot \frac{\frac{q_{\mathbf{1}}}{|q|} - c_1}{1+c_1}, |q| \cdot \sqrt{1 - (\frac{\frac{q_{\mathbf{1}}}{|q|} - c_1}{1+c_1})^{\mathbf{2}}}]$.

(59) Let c_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\mathrm{T}}$, and f be a map from $(\mathcal{E}^2_{\mathrm{T}}){\restriction}K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < c_1$,

(ii) $c_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\mathrm{T}}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\mathrm{T}}){\restriction}K_1$ holds $f(p) = |p| \cdot \frac{\frac{p_{\mathbf{1}}}{|p|} - c_1}{1-c_1}$, and

(iv) for every point q of $\mathcal{E}^2_{\mathrm{T}}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\mathrm{T}}){\restriction}K_1$ holds $q_{\mathbf{2}} \geq 0$ and $q \neq 0_{\mathcal{E}^2_{\mathrm{T}}}$.

Then f is continuous.

(60) Let c_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\bf 1}$. Suppose that

(i) $-1 < c_1$,

(ii) $c_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot \frac{\frac{p_{\bf 1}}{|p|} - c_1}{1+c_1}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\bf 2} \geq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(61) Let c_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\bf 1}$. Suppose that

(i) $-1 < c_1$,

(ii) $c_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot \sqrt{1 - (\frac{\frac{p_{\bf 1}}{|p|} - c_1}{1-c_1})^{\bf 2}}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\bf 2} \geq 0$ and $\frac{q_{\bf 1}}{|q|} \geq c_1$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(62) Let c_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\bf 1}$. Suppose that

(i) $-1 < c_1$,

(ii) $c_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot \sqrt{1 - (\frac{\frac{p_{\bf 1}}{|p|} - c_1}{1+c_1})^{\bf 2}}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\bf 2} \geq 0$ and $\frac{q_{\bf 1}}{|q|} \leq c_1$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(63) Let c_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphN$\restriction K_0$ and $B_0 = \{q; q$ ranges over points of $\mathcal{E}^2_{\rm T}$: $q_{\bf 2} \geq 0 \wedge q \neq 0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : \frac{p_{\bf 1}}{|p|} \geq c_1 \wedge p_{\bf 2} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(64) Let c_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphN$\restriction K_0$ and $B_0 = \{q; q$ ranges over points of $\mathcal{E}^2_{\rm T}$: $q_{\bf 2} \geq 0 \wedge q \neq 0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : \frac{p_{\bf 1}}{|p|} \leq c_1 \wedge p_{\bf 2} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(65) For every real number c_1 and for every subset K_3 of $\mathcal{E}^2_{\rm T}$ such that $K_3 = \{p : p_{\bf 1} \geq c_1 \cdot |p| \wedge p_{\bf 2} \geq 0\}$ holds K_3 is closed.

(66) For every real number c_1 and for every subset K_3 of $\mathcal{E}^2_{\rm T}$ such that $K_3 = \{p : p_{\bf 1} \leq c_1 \cdot |p| \wedge p_{\bf 2} \geq 0\}$ holds K_3 is closed.

(67) Let c_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphN$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\bf 2} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(68) Let c_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphN$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{2}} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(69) Let B_0 be a subset of $\mathcal{E}^2_{\rm T}$ and K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{2}} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then K_0 is closed.

(70) Let B_0 be a subset of $\mathcal{E}^2_{\rm T}$ and K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{2}} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then K_0 is closed.

(71) Let c_1 be a real number, B_0 be a subset of $\mathcal{E}^2_{\rm T}$, K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction B_0\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphN$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{2}} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(72) Let c_1 be a real number, B_0 be a subset of $\mathcal{E}^2_{\rm T}$, K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction B_0\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphN$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{2}} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(73) For every real number c_1 and for every point p of $\mathcal{E}^2_{\rm T}$ holds $|c_1$-FanMorphN$(p)| = |p|$.

(74) For every real number c_1 and for all sets x, K_0 such that $-1 < c_1$ and $c_1 < 1$ and $x \in K_0$ and $K_0 = \{p : p_{\mathbf{2}} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$ holds c_1-FanMorphN$(x) \in K_0$.

(75) For every real number c_1 and for all sets x, K_0 such that $-1 < c_1$ and $c_1 < 1$ and $x \in K_0$ and $K_0 = \{p : p_{\mathbf{2}} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$ holds c_1-FanMorphN$(x) \in K_0$.

(76) Let c_1 be a real number and D be a non empty subset of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $D^{\rm c} = \{0_{\mathcal{E}^2_{\rm T}}\}$. Then there exists a map h from $(\mathcal{E}^2_{\rm T})\restriction D$ into $(\mathcal{E}^2_{\rm T})\restriction D$ such that $h = c_1$-FanMorphN$\restriction D$ and h is continuous.

(77) Let c_1 be a real number. Suppose $-1 < c_1$ and $c_1 < 1$. Then there exists a map h from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ such that $h = c_1$-FanMorphN and h is continuous.

(78) For every real number c_1 such that $-1 < c_1$ and $c_1 < 1$ holds c_1-FanMorphN is one-to-one.

(79) For every real number c_1 such that $-1 < c_1$ and $c_1 < 1$ holds c_1-FanMorphN is a map from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ and rng(c_1-FanMorphN) = the carrier of $\mathcal{E}^2_{\rm T}$.

(80) Let c_1 be a real number and p_2 be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$. Then there exists a non empty compact subset K of $\mathcal{E}^2_{\rm T}$ such that $K = c_1$-FanMorphN$^\circ K$ and there exists a subset V_2 of $\mathcal{E}^2_{\rm T}$ such that $p_2 \in V_2$ and V_2 is open and $V_2 \subseteq K$ and c_1-FanMorphN$(p_2) \in V_2$.

(81) Let c_1 be a real number. Suppose $-1 < c_1$ and $c_1 < 1$. Then there exists a map f from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ such that $f = c_1$-FanMorphN and f is a homeomorphism.

(82) Let c_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $q_{\mathbf{2}} > 0$ and $\frac{q_{\mathbf{1}}}{|q|} \geq c_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = c_1$-FanMorphN(q), then $p_{\mathbf{2}} > 0$ and $p_{\mathbf{1}} \geq 0$.

(83) Let c_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $q_{\mathbf{2}} > 0$ and $\frac{q_{\mathbf{1}}}{|q|} < c_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = c_1$-FanMorphN(q), then $p_{\mathbf{2}} > 0$ and $p_{\mathbf{1}} < 0$.

(84) Let c_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $(q_1)_{\mathbf{2}} > 0$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} \geq c_1$ and $(q_2)_{\mathbf{2}} > 0$ and $\frac{(q_2)_{\mathbf{1}}}{|q_2|} \geq c_1$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} < \frac{(q_2)_{\mathbf{1}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = c_1$-FanMorphN(q_1) and $p_2 = c_1$-FanMorphN(q_2), then $\frac{(p_1)_{\mathbf{1}}}{|p_1|} < \frac{(p_2)_{\mathbf{1}}}{|p_2|}$.

(85) Let c_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $(q_1)_{\mathbf{2}} > 0$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} < c_1$ and $(q_2)_{\mathbf{2}} > 0$ and $\frac{(q_2)_{\mathbf{1}}}{|q_2|} < c_1$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} < \frac{(q_2)_{\mathbf{1}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = c_1$-FanMorphN(q_1) and $p_2 = c_1$-FanMorphN(q_2), then $\frac{(p_1)_{\mathbf{1}}}{|p_1|} < \frac{(p_2)_{\mathbf{1}}}{|p_2|}$.

(86) Let c_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $(q_1)_{\mathbf{2}} > 0$ and $(q_2)_{\mathbf{2}} > 0$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} < \frac{(q_2)_{\mathbf{1}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = c_1$-FanMorphN(q_1) and $p_2 = c_1$-FanMorphN(q_2), then $\frac{(p_1)_{\mathbf{1}}}{|p_1|} < \frac{(p_2)_{\mathbf{1}}}{|p_2|}$.

(87) Let c_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $q_{\mathbf{2}} > 0$ and $\frac{q_{\mathbf{1}}}{|q|} = c_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = c_1$-FanMorphN(q), then $p_{\mathbf{2}} > 0$ and $p_{\mathbf{1}} = 0$.

(88) For every real number c_1 holds $0_{\mathcal{E}^2_{\rm T}} = c_1$-FanMorphN$(0_{\mathcal{E}^2_{\rm T}})$.

4. Fan Morphism for East

Let s be a real number and let q be a point of $\mathcal{E}^2_{\rm T}$. The functor FanE(s,q) yields a point of $\mathcal{E}^2_{\rm T}$ and is defined by:

(Def. 6) $$\mathrm{FanE}(s,q) = \begin{cases} |q|\cdot[\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s}{1-s})^{\mathbf{2}}}, \frac{\frac{q_{\mathbf{2}}}{|q|}-s}{1-s}], \text{ if } \frac{q_{\mathbf{2}}}{|q|} \geq s \text{ and } q_{\mathbf{1}} > 0, \\ |q|\cdot[\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s}{1+s})^{\mathbf{2}}}, \frac{\frac{q_{\mathbf{2}}}{|q|}-s}{1+s}], \text{ if } \frac{q_{\mathbf{2}}}{|q|} < s \text{ and } q_{\mathbf{1}} > 0, \\ q, \text{ otherwise.} \end{cases}$$

Let s be a real number. The functor s-FanMorphE yields a function from the carrier of $\mathcal{E}^2_{\rm T}$ into the carrier of $\mathcal{E}^2_{\rm T}$ and is defined as follows:

(Def. 7) For every point q of $\mathcal{E}^2_{\rm T}$ holds s-FanMorphE$(q) =$ FanE(s,q).

Next we state a number of propositions:

(89) Let s_1 be a real number. Then

(i) if $\frac{q_{\mathbf{2}}}{|q|} \geq s_1$ and $q_{\mathbf{1}} > 0$, then s_1-FanMorphE$(q) = [|q|\cdot\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1-s_1})^{\mathbf{2}}}, |q|\cdot\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1-s_1}]$, and

(ii) if $q_{\mathbf{1}} \leq 0$, then s_1-FanMorphE$(q) = q$.

(90) For every real number s_1 such that $\frac{q_{\mathbf{2}}}{|q|} \leq s_1$ and $q_{\mathbf{1}} > 0$ holds s_1-FanMorphE$(q) = [|q|\cdot\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1+s_1})^{\mathbf{2}}}, |q|\cdot\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1+s_1}]$.

(91) Let s_1 be a real number such that $-1 < s_1$ and $s_1 < 1$. Then

(i) if $\frac{q_{\mathbf{2}}}{|q|} \geq s_1$ and $q_{\mathbf{1}} \geq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$, then s_1-FanMorphE$(q) = [|q|\cdot\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1-s_1})^{\mathbf{2}}}, |q|\cdot\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1-s_1}]$, and

(ii) if $\frac{q_{\mathbf{2}}}{|q|} \leq s_1$ and $q_{\mathbf{1}} \geq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$, then s_1-FanMorphE$(q) = [|q|\cdot\sqrt{1-(\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1+s_1})^{\mathbf{2}}}, |q|\cdot\frac{\frac{q_{\mathbf{2}}}{|q|}-s_1}{1+s_1}]$.

(92) Let s_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < s_1$,

(ii) $s_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p|\cdot\frac{\frac{p_{\mathbf{2}}}{|p|}-s_1}{1-s_1}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\mathbf{1}} \geq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(93) Let s_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < s_1$,

(ii) $s_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot \frac{\frac{p_{\mathbf{2}}}{|p|} - s_1}{1+s_1}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\mathbf{1}} \geq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(94) Let s_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < s_1$,

(ii) $s_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot \sqrt{1 - (\frac{\frac{p_{\mathbf{2}}}{|p|} - s_1}{1-s_1})^{\mathbf{2}}}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\mathbf{1}} \geq 0$ and $\frac{q_{\mathbf{2}}}{|q|} \geq s_1$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(95) Let s_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\mathbf{1}}$. Suppose that

(i) $-1 < s_1$,

(ii) $s_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot \sqrt{1 - (\frac{\frac{p_{\mathbf{2}}}{|p|} - s_1}{1+s_1})^{\mathbf{2}}}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\mathbf{1}} \geq 0$ and $\frac{q_{\mathbf{2}}}{|q|} \leq s_1$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(96) Let s_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphE$\restriction K_0$ and $B_0 = \{q; q$ ranges over points of $\mathcal{E}^2_{\rm T}$: $q_{\mathbf{1}} \geq 0 \land q \neq 0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : \frac{p_{\mathbf{2}}}{|p|} \geq s_1 \land p_{\mathbf{1}} \geq 0 \land p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(97) Let s_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphE$\restriction K_0$ and $B_0 = \{q; q$ ranges over points of $\mathcal{E}^2_{\rm T}$: $q_{\mathbf{1}} \geq 0 \land q \neq 0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : \frac{p_{\mathbf{2}}}{|p|} \leq s_1 \land p_{\mathbf{1}} \geq 0 \land p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(98) For every real number s_1 and for every subset K_3 of $\mathcal{E}^2_{\rm T}$ such that $K_3 = \{p : p_{\mathbf{2}} \geq s_1 \cdot |p| \land p_{\mathbf{1}} \geq 0\}$ holds K_3 is closed.

(99) For every real number s_1 and for every subset K_3 of $\mathcal{E}^2_{\rm T}$ such that $K_3 = \{p : p_{\mathbf{2}} \leq s_1 \cdot |p| \land p_{\mathbf{1}} \geq 0\}$ holds K_3 is closed.

(100) Let s_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphE$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\mathbf{1}} \geq 0 \land p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(101) Let s_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphE$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\bf 1} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(102) Let s_1 be a real number, B_0 be a subset of $\mathcal{E}^2_{\rm T}$, K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction B_0\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphE$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\bf 1} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(103) Let s_1 be a real number, B_0 be a subset of $\mathcal{E}^2_{\rm T}$, K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction B_0\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < s_1$ and $s_1 < 1$ and $f = s_1$-FanMorphE$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\bf 1} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(104) For every real number s_1 and for every point p of $\mathcal{E}^2_{\rm T}$ holds $|s_1$-FanMorphE$(p)| = |p|$.

(105) For every real number s_1 and for all sets x, K_0 such that $-1 < s_1$ and $s_1 < 1$ and $x \in K_0$ and $K_0 = \{p : p_{\bf 1} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$ holds s_1-FanMorphE$(x) \in K_0$.

(106) For every real number s_1 and for all sets x, K_0 such that $-1 < s_1$ and $s_1 < 1$ and $x \in K_0$ and $K_0 = \{p : p_{\bf 1} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$ holds s_1-FanMorphE$(x) \in K_0$.

(107) Let s_1 be a real number and D be a non empty subset of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $D^{\rm c} = \{0_{\mathcal{E}^2_{\rm T}}\}$. Then there exists a map h from $(\mathcal{E}^2_{\rm T})\restriction D$ into $(\mathcal{E}^2_{\rm T})\restriction D$ such that $h = s_1$-FanMorphE$\restriction D$ and h is continuous.

(108) Let s_1 be a real number. Suppose $-1 < s_1$ and $s_1 < 1$. Then there exists a map h from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ such that $h = s_1$-FanMorphE and h is continuous.

(109) For every real number s_1 such that $-1 < s_1$ and $s_1 < 1$ holds s_1-FanMorphE is one-to-one.

(110) For every real number s_1 such that $-1 < s_1$ and $s_1 < 1$ holds s_1-FanMorphE is a map from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ and rng(s_1-FanMorphE) = the carrier of $\mathcal{E}^2_{\rm T}$.

(111) Let s_1 be a real number and p_2 be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$. Then there exists a non empty compact subset K of $\mathcal{E}^2_{\rm T}$ such that $K = s_1$-FanMorphE$^\circ K$ and there exists a subset V_2 of $\mathcal{E}^2_{\rm T}$ such that $p_2 \in V_2$ and V_2 is open and $V_2 \subseteq K$ and s_1-FanMorphE$(p_2) \in V_2$.

(112) Let s_1 be a real number. Suppose $-1 < s_1$ and $s_1 < 1$. Then there exists a map f from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ such that $f = s_1$-FanMorphE and f is a homeomorphism.

(113) Let s_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $q_{\bf 1} > 0$ and $\frac{q_{\bf 2}}{|q|} \geq s_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = s_1$-FanMorphE(q), then $p_{\bf 1} > 0$ and $p_{\bf 2} \geq 0$.

(114) Let s_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $q_{\bf 1} > 0$ and $\frac{q_{\bf 2}}{|q|} < s_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = s_1$-FanMorphE(q), then $p_{\bf 1} > 0$ and $p_{\bf 2} < 0$.

(115) Let s_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $(q_1)_{\bf 1} > 0$ and $\frac{(q_1)_{\bf 2}}{|q_1|} \geq s_1$ and $(q_2)_{\bf 1} > 0$ and $\frac{(q_2)_{\bf 2}}{|q_2|} \geq s_1$ and $\frac{(q_1)_{\bf 2}}{|q_1|} < \frac{(q_2)_{\bf 2}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = s_1$-FanMorphE(q_1) and $p_2 = s_1$-FanMorphE(q_2), then $\frac{(p_1)_{\bf 2}}{|p_1|} < \frac{(p_2)_{\bf 2}}{|p_2|}$.

(116) Let s_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $(q_1)_{\bf 1} > 0$ and $\frac{(q_1)_{\bf 2}}{|q_1|} < s_1$ and $(q_2)_{\bf 1} > 0$ and $\frac{(q_2)_{\bf 2}}{|q_2|} < s_1$ and $\frac{(q_1)_{\bf 2}}{|q_1|} < \frac{(q_2)_{\bf 2}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = s_1$-FanMorphE(q_1) and $p_2 = s_1$-FanMorphE(q_2), then $\frac{(p_1)_{\bf 2}}{|p_1|} < \frac{(p_2)_{\bf 2}}{|p_2|}$.

(117) Let s_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $(q_1)_{\bf 1} > 0$ and $(q_2)_{\bf 1} > 0$ and $\frac{(q_1)_{\bf 2}}{|q_1|} < \frac{(q_2)_{\bf 2}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = s_1$-FanMorphE(q_1) and $p_2 = s_1$-FanMorphE(q_2), then $\frac{(p_1)_{\bf 2}}{|p_1|} < \frac{(p_2)_{\bf 2}}{|p_2|}$.

(118) Let s_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < s_1$ and $s_1 < 1$ and $q_{\bf 1} > 0$ and $\frac{q_{\bf 2}}{|q|} = s_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = s_1$-FanMorphE(q), then $p_{\bf 1} > 0$ and $p_{\bf 2} = 0$.

(119) For every real number s_1 holds $0_{\mathcal{E}^2_{\rm T}} = s_1$-FanMorphE$(0_{\mathcal{E}^2_{\rm T}})$.

5. Fan Morphism for South

Let s be a real number and let q be a point of $\mathcal{E}^2_{\rm T}$. The functor FanS(s,q) yielding a point of $\mathcal{E}^2_{\rm T}$ is defined as follows:

(Def. 8) $$\mathrm{FanS}(s,q) = \begin{cases} |q| \cdot [\frac{\frac{q_{\bf 1}}{|q|}-s}{1-s}, -\sqrt{1-(\frac{\frac{q_{\bf 1}}{|q|}-s}{1-s})^{\bf 2}}], \text{ if } \frac{q_{\bf 1}}{|q|} \geq s \text{ and } q_{\bf 2} < 0, \\ |q| \cdot [\frac{\frac{q_{\bf 1}}{|q|}-s}{1+s}, -\sqrt{1-(\frac{\frac{q_{\bf 1}}{|q|}-s}{1+s})^{\bf 2}}], \text{ if } \frac{q_{\bf 1}}{|q|} < s \text{ and } q_{\bf 2} < 0, \\ q, \text{ otherwise.} \end{cases}$$

Let c be a real number. The functor c-FanMorphS yields a function from the carrier of $\mathcal{E}^2_{\rm T}$ into the carrier of $\mathcal{E}^2_{\rm T}$ and is defined by:

(Def. 9) For every point q of $\mathcal{E}^2_{\rm T}$ holds c-FanMorphS$(q) = $ FanS(c,q).

One can prove the following propositions:

(120) Let c_1 be a real number. Then

- (i) if $\frac{q_{\bf 1}}{|q|} \geq c_1$ and $q_{\bf 2} < 0$, then c_1-FanMorphS$(q) = [|q| \cdot \frac{\frac{q_{\bf 1}}{|q|}-c_1}{1-c_1}, |q| \cdot -\sqrt{1-(\frac{\frac{q_{\bf 1}}{|q|}-c_1}{1-c_1})^{\bf 2}}]$, and
- (ii) if $q_{\bf 2} \geq 0$, then c_1-FanMorphS$(q) = q$.

(121) For every real number c_1 such that $\frac{q_{\bf 1}}{|q|} \leq c_1$ and $q_{\bf 2} < 0$ holds c_1-FanMorphS$(q) = [|q| \cdot \frac{\frac{q_{\bf 1}}{|q|}-c_1}{1+c_1}, |q| \cdot -\sqrt{1-(\frac{\frac{q_{\bf 1}}{|q|}-c_1}{1+c_1})^{\bf 2}}]$.

(122) Let c_1 be a real number such that $-1 < c_1$ and $c_1 < 1$. Then

- (i) if $\frac{q_{\bf 1}}{|q|} \geq c_1$ and $q_{\bf 2} \leq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$, then c_1-FanMorphS$(q) = [|q| \cdot \frac{\frac{q_{\bf 1}}{|q|}-c_1}{1-c_1}, |q| \cdot -\sqrt{1-(\frac{\frac{q_{\bf 1}}{|q|}-c_1}{1-c_1})^{\bf 2}}]$, and
- (ii) if $\frac{q_{\bf 1}}{|q|} \leq c_1$ and $q_{\bf 2} \leq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$, then c_1-FanMorphS$(q) = [|q| \cdot \frac{\frac{q_{\bf 1}}{|q|}-c_1}{1+c_1}, |q| \cdot -\sqrt{1-(\frac{\frac{q_{\bf 1}}{|q|}-c_1}{1+c_1})^{\bf 2}}]$.

(123) Let c_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T}) \restriction K_1$ into $\mathbb{R}^{\bf 1}$. Suppose that

- (i) $-1 < c_1$,
- (ii) $c_1 < 1$,
- (iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T}) \restriction K_1$ holds $f(p) = |p| \cdot \frac{\frac{p_{\bf 1}}{|p|}-c_1}{1-c_1}$, and
- (iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T}) \restriction K_1$ holds $q_{\bf 2} \leq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(124) Let c_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T}) \restriction K_1$ into $\mathbb{R}^{\bf 1}$. Suppose that

- (i) $-1 < c_1$,
- (ii) $c_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot \frac{\frac{p_{\bf 1}}{|p|} - c_1}{1+c_1}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\bf 2} \leq 0$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(125) Let c_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\bf 1}$. Suppose that

(i) $-1 < c_1$,

(ii) $c_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot -\sqrt{1 - (\frac{\frac{p_{\bf 1}}{|p|} - c_1}{1-c_1})^{\bf 2}}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\bf 2} \leq 0$ and $\frac{q_{\bf 1}}{|q|} \geq c_1$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(126) Let c_1 be a real number, K_1 be a non empty subset of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_1$ into $\mathbb{R}^{\bf 1}$. Suppose that

(i) $-1 < c_1$,

(ii) $c_1 < 1$,

(iii) for every point p of $\mathcal{E}^2_{\rm T}$ such that $p \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $f(p) = |p| \cdot -\sqrt{1 - (\frac{\frac{p_{\bf 1}}{|p|} - c_1}{1+c_1})^{\bf 2}}$, and

(iv) for every point q of $\mathcal{E}^2_{\rm T}$ such that $q \in$ the carrier of $(\mathcal{E}^2_{\rm T})\restriction K_1$ holds $q_{\bf 2} \leq 0$ and $\frac{q_{\bf 1}}{|q|} \leq c_1$ and $q \neq 0_{\mathcal{E}^2_{\rm T}}$.

Then f is continuous.

(127) Let c_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphS$\restriction K_0$ and $B_0 = \{q; q$ ranges over points of $\mathcal{E}^2_{\rm T}$: $q_{\bf 2} \leq 0 \wedge q \neq 0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : \frac{p_{\bf 1}}{|p|} \geq c_1 \wedge p_{\bf 2} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(128) Let c_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphS$\restriction K_0$ and $B_0 = \{q; q$ ranges over points of $\mathcal{E}^2_{\rm T}$: $q_{\bf 2} \leq 0 \wedge q \neq 0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : \frac{p_{\bf 1}}{|p|} \leq c_1 \wedge p_{\bf 2} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(129) For every real number c_1 and for every subset K_3 of $\mathcal{E}^2_{\rm T}$ such that $K_3 = \{p : p_{\bf 1} \geq c_1 \cdot |p| \wedge p_{\bf 2} \leq 0\}$ holds K_3 is closed.

(130) For every real number c_1 and for every subset K_3 of $\mathcal{E}^2_{\rm T}$ such that $K_3 = \{p : p_{\bf 1} \leq c_1 \cdot |p| \wedge p_{\bf 2} \leq 0\}$ holds K_3 is closed.

(131) Let c_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphS$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\bf 2} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(132) Let c_1 be a real number, K_0, B_0 be subsets of $\mathcal{E}^2_{\rm T}$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphS$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\bf 2} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

(133) Let c_1 be a real number, B_0 be a subset of $\mathcal{E}^2_{\rm T}$, K_0 be a subset of $(\mathcal{E}^2_{\rm T})\restriction B_0$, and f be a map from $(\mathcal{E}^2_{\rm T})\restriction B_0\restriction K_0$ into $(\mathcal{E}^2_{\rm T})\restriction B_0$. Suppose $-1 < c_1$ and $c_1 < 1$ and $f = c_1$-FanMorphS$\restriction K_0$ and $B_0 =$ (the carrier of $\mathcal{E}^2_{\rm T}) \setminus \{0_{\mathcal{E}^2_{\rm T}}\}$ and $K_0 = \{p : p_{\bf 2} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$. Then f is continuous.

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(135) For every real number c_1 and for every point p of $\mathcal{E}^2_{\rm T}$ holds $|c_1$-FanMorphS$(p)| = |p|$.

(136) For every real number c_1 and for all sets x, K_0 such that $-1 < c_1$ and $c_1 < 1$ and $x \in K_0$ and $K_0 = \{p : p_{\mathbf{2}} \leq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$ holds c_1-FanMorphS$(x) \in K_0$.

(137) For every real number c_1 and for all sets x, K_0 such that $-1 < c_1$ and $c_1 < 1$ and $x \in K_0$ and $K_0 = \{p : p_{\mathbf{2}} \geq 0 \wedge p \neq 0_{\mathcal{E}^2_{\rm T}}\}$ holds c_1-FanMorphS$(x) \in K_0$.

(138) Let c_1 be a real number and D be a non empty subset of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $D^{\rm c} = \{0_{\mathcal{E}^2_{\rm T}}\}$. Then there exists a map h from $(\mathcal{E}^2_{\rm T})\restriction D$ into $(\mathcal{E}^2_{\rm T})\restriction D$ such that $h = c_1$-FanMorphS$\restriction D$ and h is continuous.

(139) Let c_1 be a real number. Suppose $-1 < c_1$ and $c_1 < 1$. Then there exists a map h from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ such that $h = c_1$-FanMorphS and h is continuous.

(140) For every real number c_1 such that $-1 < c_1$ and $c_1 < 1$ holds c_1-FanMorphS is one-to-one.

(141) For every real number c_1 such that $-1 < c_1$ and $c_1 < 1$ holds c_1-FanMorphS is a map from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ and rng$(c_1$-FanMorphS$) =$ the carrier of $\mathcal{E}^2_{\rm T}$.

(142) Let c_1 be a real number and p_2 be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$. Then there exists a non empty compact subset K of $\mathcal{E}^2_{\rm T}$ such that $K = c_1$-FanMorphS$^\circ K$ and there exists a subset V_2 of $\mathcal{E}^2_{\rm T}$ such that $p_2 \in V_2$ and V_2 is open and $V_2 \subseteq K$ and c_1-FanMorphS$(p_2) \in V_2$.

(143) Let c_1 be a real number. Suppose $-1 < c_1$ and $c_1 < 1$. Then there exists a map f from $\mathcal{E}^2_{\rm T}$ into $\mathcal{E}^2_{\rm T}$ such that $f = c_1$-FanMorphS and f is a homeomorphism.

(144) Let c_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $q_{\mathbf{2}} < 0$ and $\frac{q_{\mathbf{1}}}{|q|} \geq c_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = c_1$-FanMorphS(q), then $p_{\mathbf{2}} < 0$ and $p_{\mathbf{1}} \geq 0$.

(145) Let c_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $q_{\mathbf{2}} < 0$ and $\frac{q_{\mathbf{1}}}{|q|} < c_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = c_1$-FanMorphS(q), then $p_{\mathbf{2}} < 0$ and $p_{\mathbf{1}} < 0$.

(146) Let c_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $(q_1)_{\mathbf{2}} < 0$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} \geq c_1$ and $(q_2)_{\mathbf{2}} < 0$ and $\frac{(q_2)_{\mathbf{1}}}{|q_2|} \geq c_1$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} < \frac{(q_2)_{\mathbf{1}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = c_1$-FanMorphS(q_1) and $p_2 = c_1$-FanMorphS(q_2), then $\frac{(p_1)_{\mathbf{1}}}{|p_1|} < \frac{(p_2)_{\mathbf{1}}}{|p_2|}$.

(147) Let c_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $(q_1)_{\mathbf{2}} < 0$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} < c_1$ and $(q_2)_{\mathbf{2}} < 0$ and $\frac{(q_2)_{\mathbf{1}}}{|q_2|} < c_1$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} < \frac{(q_2)_{\mathbf{1}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = c_1$-FanMorphS(q_1) and $p_2 = c_1$-FanMorphS(q_2), then $\frac{(p_1)_{\mathbf{1}}}{|p_1|} < \frac{(p_2)_{\mathbf{1}}}{|p_2|}$.

(148) Let c_1 be a real number and q_1, q_2 be points of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $(q_1)_{\mathbf{2}} < 0$ and $(q_2)_{\mathbf{2}} < 0$ and $\frac{(q_1)_{\mathbf{1}}}{|q_1|} < \frac{(q_2)_{\mathbf{1}}}{|q_2|}$. Let p_1, p_2 be points of $\mathcal{E}^2_{\rm T}$. If $p_1 = c_1$-FanMorphS(q_1) and $p_2 = c_1$-FanMorphS(q_2), then $\frac{(p_1)_{\mathbf{1}}}{|p_1|} < \frac{(p_2)_{\mathbf{1}}}{|p_2|}$.

(149) Let c_1 be a real number and q be a point of $\mathcal{E}^2_{\rm T}$. Suppose $-1 < c_1$ and $c_1 < 1$ and $q_{\mathbf{2}} < 0$ and $\frac{q_{\mathbf{1}}}{|q|} = c_1$. Let p be a point of $\mathcal{E}^2_{\rm T}$. If $p = c_1$-FanMorphS(q), then $p_{\mathbf{2}} < 0$ and $p_{\mathbf{1}} = 0$.

(150) For every real number c_1 holds $0_{\mathcal{E}^2_{\rm T}} = c_1$-FanMorphS$(0_{\mathcal{E}^2_{\rm T}})$.

References

[1] Grzegorz Bancerek. The ordinal numbers. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/ordinal1.html.

[2] Leszek Borys. Paracompact and metrizable spaces. *Journal of Formalized Mathematics*, 3, 1991. http://mizar.org/JFM/Vol3/pcomps_1.html.

[3] Czesław Byliński. Functions and their basic properties. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/funct_1.html.

[4] Czesław Byliński. Functions from a set to a set. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/funct_2.html.

[5] Czesław Byliński. Partial functions. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/partfun1.html.

[6] Czesław Byliński and Piotr Rudnicki. Bounding boxes for compact sets in $\mathcal{E}^2$. *Journal of Formalized Mathematics*, 9, 1997. http://mizar.org/JFM/Vol9/pscomp_1.html.

[7] Agata Darmochwał. Compact spaces. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/compts_1.html.

[8] Agata Darmochwał. Families of subsets, subspaces and mappings in topological spaces. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/tops_2.html.

[9] Agata Darmochwał. The Euclidean space. *Journal of Formalized Mathematics*, 3, 1991. http://mizar.org/JFM/Vol3/euclid.html.

[10] Agata Darmochwał and Yatsuka Nakamura. Metric spaces as topological spaces — fundamental concepts. *Journal of Formalized Mathematics*, 3, 1991. http://mizar.org/JFM/Vol3/topmetr.html.

[11] Krzysztof Hryniewiecki. Basic properties of real numbers. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/real_1.html.

[12] Stanisława Kanas, Adam Lecko, and Mariusz Startek. Metric spaces. *Journal of Formalized Mathematics*, 2, 1990. http://mizar.org/JFM/Vol2/metric_1.html.

[13] Yatsuka Nakamura, Andrzej Trybulec, and Czesław Byliński. Bounded domains and unbounded domains. *Journal of Formalized Mathematics*, 11, 1999. http://mizar.org/JFM/Vol11/jordan2c.html.

[14] Beata Padlewska and Agata Darmochwał. Topological spaces and continuous functions. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/pre_topc.html.

[15] Jan Popiołek. Some properties of functions modul and signum. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/absvalue.html.

[16] Andrzej Trybulec. Tarski Grothendieck set theory. *Journal of Formalized Mathematics*, Axiomatics, 1989. http://mizar.org/JFM/Axiomatics/tarski.html.

[17] Andrzej Trybulec and Czesław Byliński. Some properties of real numbers operations: min, max, square, and square root. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/square_1.html.

[18] Zinaida Trybulec. Properties of subsets. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/subset_1.html.

[19] Edmund Woronowicz. Relations and their basic properties. *Journal of Formalized Mathematics*, 1, 1989. http://mizar.org/JFM/Vol1/relat_1.html.

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