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Binary Operations Applied to Finite Sequences

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Summary. The article contains some propositions and theorems related to [9] and [8]. The notions introduced in [9] are extended to finite sequences. A number of additional propositions related to this notions are proved. There are also proved some properties of distributive operations and unary operations. The notation and propositions for inverses are introduced.

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

For simplicity, we follow the rules: x, y denote sets, C, C', D, D', E denote non empty sets, c denotes an element of C, c' denotes an element of C', d, d_1, d_2, d_3, d_4, e denote elements of D, and d' denotes an element of D'.

We now state several propositions:

(1) For every function f holds $\langle \emptyset, f \rangle = \emptyset$ and $\langle f, \emptyset \rangle = \emptyset$.

(2) For every function f holds $[\!:\emptyset, f:\!] = \emptyset$ and $[\!: f, \emptyset :\!] = \emptyset$.

(4)[1] For all functions F, f holds $F^\circ(\emptyset, f) = \emptyset$ and $F^\circ(f, \emptyset) = \emptyset$.

(5) For every function F holds $F^\circ(\emptyset, x) = \emptyset$.

(6) For every function F holds $F^\circ(x, \emptyset) = \emptyset$.

(7) For every set X and for all sets x_1, x_2 holds $\langle X \longmapsto x_1, X \longmapsto x_2 \rangle = X \longmapsto \langle\!\langle x_1, x_2 \rangle\!\rangle$.

(8) For every function F and for every set X and for all sets x_1, x_2 such that $\langle\!\langle x_1, x_2 \rangle\!\rangle \in \operatorname{dom} F$ holds $F^\circ(X \longmapsto x_1, X \longmapsto x_2) = X \longmapsto F(\langle\!\langle x_1, x_2 \rangle\!\rangle)$.

For simplicity, we follow the rules: i, j denote natural numbers, F denotes a function from $[\!: D, D' :\!]$ into E, p, q denote finite sequences of elements of D, and p', q' denote finite sequences of elements of D'.

Let us consider D, D', E, F, p, p'. Then $F^\circ(p, p')$ is a finite sequence of elements of E.

Let us consider D, D', E, F, p, d'. Then $F^\circ(p, d')$ is a finite sequence of elements of E.

Let us consider D, D', E, F, d, p'. Then $F^\circ(d, p')$ is a finite sequence of elements of E.

Let us consider D, i, d. Then $i \mapsto d$ is an element of D^i.

In the sequel f, f' denote functions from C into D and h denotes a function from D into E.

[1] The proposition (3) has been removed.

Let D, E be sets, let p be a finite sequence of elements of D, and let h be a function from D into E. Then $h \cdot p$ is a finite sequence of elements of E.

One can prove the following propositions:

(9) $h \cdot (p \frown \langle d \rangle) = (h \cdot p) \frown \langle h(d) \rangle$.

(10) $h \cdot (p \frown q) = (h \cdot p) \frown (h \cdot q)$.

For simplicity, we adopt the following convention: T, T_1, T_2, T_3 are elements of D^i, T' is an element of D'^i, S is an element of D^j, and S' is an element of D'^j.

We now state a number of propositions:

(11) $F^\circ(T \frown \langle d \rangle, T' \frown \langle d' \rangle) = (F^\circ(T, T')) \frown \langle F(d, d') \rangle$.

(12) $F^\circ(T \frown S, T' \frown S') = (F^\circ(T, T')) \frown F^\circ(S, S')$.

(13) $F^\circ(d, p' \frown \langle d' \rangle) = (F^\circ(d, p')) \frown \langle F(d, d') \rangle$.

(14) $F^\circ(d, p' \frown q') = (F^\circ(d, p')) \frown F^\circ(d, q')$.

(15) $F^\circ(p \frown \langle d \rangle, d') = (F^\circ(p, d')) \frown \langle F(d, d') \rangle$.

(16) $F^\circ(p \frown q, d') = (F^\circ(p, d')) \frown F^\circ(q, d')$.

(17) For every function h from D into E holds $h \cdot (i \mapsto d) = i \mapsto h(d)$.

(18) $F^\circ(i \mapsto d, i \mapsto d') = i \mapsto F(d, d')$.

(19) $F^\circ(d, i \mapsto d') = i \mapsto F(d, d')$.

(20) $F^\circ(i \mapsto d, d') = i \mapsto F(d, d')$.

(21) $F^\circ(i \mapsto d, T') = F^\circ(d, T')$.

(22) $F^\circ(T, i \mapsto d) = F^\circ(T, d)$.

(23) $F^\circ(d, T') = F^\circ(d, \mathrm{id}_{D'}) \cdot T'$.

(24) $F^\circ(T, d) = F^\circ(\mathrm{id}_D, d) \cdot T$.

In the sequel F, G are binary operations on D, u is a unary operation on D, and H is a binary operation on E.

Next we state a number of propositions:

(25) If F is associative, then $F^\circ(d, \mathrm{id}_D) \cdot F^\circ(f, f') = F^\circ(F^\circ(d, \mathrm{id}_D) \cdot f, f')$.

(26) If F is associative, then $F^\circ(\mathrm{id}_D, d) \cdot F^\circ(f, f') = F^\circ(f, F^\circ(\mathrm{id}_D, d) \cdot f')$.

(27) If F is associative, then $F^\circ(d, \mathrm{id}_D) \cdot F^\circ(T_1, T_2) = F^\circ(F^\circ(d, \mathrm{id}_D) \cdot T_1, T_2)$.

(28) If F is associative, then $F^\circ(\mathrm{id}_D, d) \cdot F^\circ(T_1, T_2) = F^\circ(T_1, F^\circ(\mathrm{id}_D, d) \cdot T_2)$.

(29) If F is associative, then $F^\circ(F^\circ(T_1, T_2), T_3) = F^\circ(T_1, F^\circ(T_2, T_3))$.

(30) If F is associative, then $F^\circ(F^\circ(d_1, T), d_2) = F^\circ(d_1, F^\circ(T, d_2))$.

(31) If F is associative, then $F^\circ(F^\circ(T_1, d), T_2) = F^\circ(T_1, F^\circ(d, T_2))$.

(32) If F is associative, then $F^\circ(F(d_1, d_2), T) = F^\circ(d_1, F^\circ(d_2, T))$.

(33) If F is associative, then $F^\circ(T, F(d_1, d_2)) = F^\circ(F^\circ(T, d_1), d_2)$.

(34) If F is commutative, then $F^\circ(T_1, T_2) = F^\circ(T_2, T_1)$.

(35) If F is commutative, then $F^\circ(d, T) = F^\circ(T, d)$.

(36) If F is distributive w.r.t. G, then $F^\circ(G(d_1, d_2), f) = G^\circ(F^\circ(d_1, f), F^\circ(d_2, f))$.

(37) If F is distributive w.r.t. G, then $F^\circ(f, G(d_1, d_2)) = G^\circ(F^\circ(f, d_1), F^\circ(f, d_2))$.

(38) If for all d_1, d_2 holds $h(F(d_1, d_2)) = H(h(d_1), h(d_2))$, then $h \cdot F^\circ(f, f') = H^\circ(h \cdot f, h \cdot f')$.

(39) If for all d_1, d_2 holds $h(F(d_1, d_2)) = H(h(d_1), h(d_2))$, then $h \cdot F^\circ(d, f) = H^\circ(h(d), h \cdot f)$.

(40) If for all d_1, d_2 holds $h(F(d_1, d_2)) = H(h(d_1), h(d_2))$, then $h \cdot F^\circ(f, d) = H^\circ(h \cdot f, h(d))$.

(41) If u is distributive w.r.t. F, then $u \cdot F^\circ(f, f') = F^\circ(u \cdot f, u \cdot f')$.

(42) If u is distributive w.r.t. F, then $u \cdot F^\circ(d, f) = F^\circ(u(d), u \cdot f)$.

(43) If u is distributive w.r.t. F, then $u \cdot F^\circ(f, d) = F^\circ(u \cdot f, u(d))$.

(44) If F has a unity, then $F^\circ(C \longmapsto \mathbf{1}_F, f) = f$ and $F^\circ(f, C \longmapsto \mathbf{1}_F) = f$.

(45) If F has a unity, then $F^\circ(\mathbf{1}_F, f) = f$.

(46) If F has a unity, then $F^\circ(f, \mathbf{1}_F) = f$.

(47) If F is distributive w.r.t. G, then $F^\circ(G(d_1, d_2), T) = G^\circ(F^\circ(d_1, T), F^\circ(d_2, T))$.

(48) If F is distributive w.r.t. G, then $F^\circ(T, G(d_1, d_2)) = G^\circ(F^\circ(T, d_1), F^\circ(T, d_2))$.

(49) If for all d_1, d_2 holds $h(F(d_1, d_2)) = H(h(d_1), h(d_2))$, then $h \cdot F^\circ(T_1, T_2) = H^\circ(h \cdot T_1, h \cdot T_2)$.

(50) If for all d_1, d_2 holds $h(F(d_1, d_2)) = H(h(d_1), h(d_2))$, then $h \cdot F^\circ(d, T) = H^\circ(h(d), h \cdot T)$.

(51) If for all d_1, d_2 holds $h(F(d_1, d_2)) = H(h(d_1), h(d_2))$, then $h \cdot F^\circ(T, d) = H^\circ(h \cdot T, h(d))$.

(52) If u is distributive w.r.t. F, then $u \cdot F^\circ(T_1, T_2) = F^\circ(u \cdot T_1, u \cdot T_2)$.

(53) If u is distributive w.r.t. F, then $u \cdot F^\circ(d, T) = F^\circ(u(d), u \cdot T)$.

(54) If u is distributive w.r.t. F, then $u \cdot F^\circ(T, d) = F^\circ(u \cdot T, u(d))$.

(55) If G is distributive w.r.t. F and $u = G^\circ(d, \mathrm{id}_D)$, then u is distributive w.r.t. F.

(56) If G is distributive w.r.t. F and $u = G^\circ(\mathrm{id}_D, d)$, then u is distributive w.r.t. F.

(57) If F has a unity, then $F^\circ(i \mapsto \mathbf{1}_F, T) = T$ and $F^\circ(T, i \mapsto \mathbf{1}_F) = T$.

(58) If F has a unity, then $F^\circ(\mathbf{1}_F, T) = T$.

(59) If F has a unity, then $F^\circ(T, \mathbf{1}_F) = T$.

Let us consider D, u, F. We say that u is an inverse operation w.r.t. F if and only if:

(Def. 1) For every d holds $F(d, u(d)) = \mathbf{1}_F$ and $F(u(d), d) = \mathbf{1}_F$.

Let us consider D, F. We say that F if and only if:

(Def. 2) There exists u which is an inverse operation w.r.t. F.

We introduce F has an inverse operation as a synonym of F
let us consider D, F. Let us assume that F has a unity F is associative and F has an inverse operation. The inverse operation w.r.t. F yields a unary operation on D and is defined by:

(Def. 3) The inverse operation w.r.t. F is an inverse operation w.r.t. F.

One can prove the following propositions:

(63)[2] Suppose F is associative and has a unity and an inverse operation. Then $F(($the inverse operation w.r.t. $F)(d), d) = \mathbf{1}_F$ and $F(d, ($the inverse operation w.r.t. $F)(d)) = \mathbf{1}_F$.

[2] The propositions (60)–(62) have been removed.

(64) Suppose F is associative and has a unity and an inverse operation and $F(d_1, d_2) = \mathbf{1}_F$. Then $d_1 =$ (the inverse operation w.r.t. F)(d_2) and (the inverse operation w.r.t. F)$(d_1) = d_2$.

(65) If F is associative and has a unity and an inverse operation, then (the inverse operation w.r.t. F)$(\mathbf{1}_F) = \mathbf{1}_F$.

(66) If F is associative and has a unity and an inverse operation, then (the inverse operation w.r.t. F)((the inverse operation w.r.t. F)$(d)) = d$.

(67) Suppose F is associative and commutative and has a unity and an inverse operation. Then the inverse operation w.r.t. F is distributive w.r.t. F.

(68) If F is associative and has a unity and an inverse operation and if $F(d, d_1) = F(d, d_2)$ or $F(d_1, d) = F(d_2, d)$, then $d_1 = d_2$.

(69) If F is associative and has a unity and an inverse operation and if $F(d_1, d_2) = d_2$ or $F(d_2, d_1) = d_2$, then $d_1 = \mathbf{1}_F$.

(70) Suppose F is associative and has a unity and an inverse operation and G is distributive w.r.t. F and $e = \mathbf{1}_F$. Let given d. Then $G(e, d) = e$ and $G(d, e) = e$.

(71) Suppose F is associative and has a unity and an inverse operation and $u =$ the inverse operation w.r.t. F and G is distributive w.r.t. F. Then $u(G(d_1, d_2)) = G(u(d_1), d_2)$ and $u(G(d_1, d_2)) = G(d_1, u(d_2))$.

(72) Suppose F is associative and has a unity and an inverse operation and $u =$ the inverse operation w.r.t. F and G is distributive w.r.t. F and has a unity. Then $G^\circ(u(\mathbf{1}_G), \mathrm{id}_D) = u$.

(73) If F is associative and has a unity and an inverse operation and G is distributive w.r.t. F, then $(G^\circ(d, \mathrm{id}_D))(\mathbf{1}_F) = \mathbf{1}_F$.

(74) If F is associative and has a unity and an inverse operation and G is distributive w.r.t. F, then $(G^\circ(\mathrm{id}_D, d))(\mathbf{1}_F) = \mathbf{1}_F$.

(75) Suppose F is associative and has a unity and an inverse operation. Then $F^\circ(f,$ (the inverse operation w.r.t. F)$\cdot f) = C \longmapsto \mathbf{1}_F$ and F°((the inverse operation w.r.t. F)$\cdot f, f) = C \longmapsto \mathbf{1}_F$.

(76) Suppose F is associative and has an inverse operation and a unity and $F^\circ(f, f') = C \longmapsto \mathbf{1}_F$. Then $f =$ (the inverse operation w.r.t. F)$\cdot f'$ and (the inverse operation w.r.t. F)$\cdot f = f'$.

(77) Suppose F is associative and has a unity and an inverse operation. Then $F^\circ(T,$ (the inverse operation w.r.t. F)$\cdot T) = i \mapsto \mathbf{1}_F$ and F°((the inverse operation w.r.t. F)$\cdot T, T) = i \mapsto \mathbf{1}_F$.

(78) Suppose F is associative and has an inverse operation and a unity and $F^\circ(T_1, T_2) = i \mapsto \mathbf{1}_F$. Then $T_1 =$ (the inverse operation w.r.t. F)$\cdot T_2$ and (the inverse operation w.r.t. F)$\cdot T_1 = T_2$.

(79) If F is associative and has a unity and $e = \mathbf{1}_F$ and F has an inverse operation and G is distributive w.r.t. F, then $G^\circ(e, f) = C \longmapsto e$.

(80) If F is associative and has a unity and $e = \mathbf{1}_F$ and F has an inverse operation and G is distributive w.r.t. F, then $G^\circ(e, T) = i \mapsto e$.

Let F, f, g be functions. The functor $F \circ (f, g)$ yields a function and is defined as follows:

(Def. 4) $F \circ (f, g) = F \cdot [: f, g :]$.

The following four propositions are true:

(82)[3] For all functions F, f, g such that $\langle x, y \rangle \in \mathrm{dom}(F \circ (f, g))$ holds $(F \circ (f, g))(\langle x, y \rangle) = F(\langle f(x), g(y) \rangle)$.

[3] The proposition (81) has been removed.

(83) For all functions F, f, g such that $\langle x, y\rangle \in \operatorname{dom}(F \circ (f,g))$ holds $(F \circ (f,g))(x, y) = F(f(x), g(y))$.

(84) Let F be a function from $[:D, D':]$ into E, f be a function from C into D, and g be a function from C' into D'. Then $F \circ (f,g)$ is a function from $[:C, C':]$ into E.

(85) For all functions u, u' from D into D holds $F \circ (u,u')$ is a binary operation on D.

Let us consider D, F and let f, f' be functions from D into D. Then $F \circ (f, f')$ is a binary operation on D.

We now state several propositions:

(86) Let F be a function from $[:D, D':]$ into E, f be a function from C into D, and g be a function from C' into D'. Then $(F \circ (f,g))(c, c') = F(f(c), g(c'))$.

(87) For every function u from D into D holds $(F \circ (\mathrm{id}_D,u))(d_1, d_2) = F(d_1, u(d_2))$ and $(F \circ (u,\mathrm{id}_D))(d_1, d_2) = F(u(d_1), d_2)$.

(88) $(F \circ (\mathrm{id}_D,u))^\circ(f, f') = F^\circ(f, u \cdot f')$.

(89) $(F \circ (\mathrm{id}_D,u))^\circ(T_1, T_2) = F^\circ(T_1, u \cdot T_2)$.

(90) Suppose F is associative and commutative and has a unity and an inverse operation and $u =$ the inverse operation w.r.t. F. Then $u((F \circ (\mathrm{id}_D,u))(d_1, d_2)) = (F \circ (u,\mathrm{id}_D))(d_1, d_2)$ and $(F \circ (\mathrm{id}_D,u))(d_1, d_2) = u((F \circ (u,\mathrm{id}_D))(d_1, d_2))$.

(91) If F is associative and has a unity and an inverse operation, then $(F \circ (\mathrm{id}_D,$ the inverse operation w.r.t. $F))(d, d) = \mathbf{1}_F$.

(92) If F is associative and has a unity and an inverse operation, then $(F \circ (\mathrm{id}_D,$ the inverse operation w.r.t. $F))(d, \mathbf{1}_F) = d$.

(93) If F is associative and has a unity and an inverse operation and $u =$ the inverse operation w.r.t. F, then $(F \circ (\mathrm{id}_D,u))(\mathbf{1}_F, d) = u(d)$.

(94) Suppose F is commutative and associative and has a unity and an inverse operation and $G = F \circ (\mathrm{id}_D,$ the inverse operation w.r.t. $F)$. Let given d_1, d_2, d_3, d_4. Then $F(G(d_1, d_2), G(d_3, d_4)) = G(F(d_1, d_3), F(d_2, d_4))$.

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