JOURNAL OF FORMALIZED MATHEMATICS
Volume 13, Released 2001, Published 2003
Inst. of Computer Science, Univ. of Białystok

Yet Another Construction of Free Algebra

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MML Identifier: MSAFREE3.

WWW: http://mizar.org/JFM/Vol13/msafree3.html

The articles [25], [14], [30], [24], [31], [13], [32], [29], [26], [16], [2], [10], [22], [1], [4], [3], [5], [6], [11], [15], [27], [28], [12], [20], [23], [21], [19], [17], [18], [7], [8], and [9] provide the notation and terminology for this paper.

In this paper X, x, z denote sets.

Let S be a non empty non void many sorted signature and let A be a non empty algebra over S. Observe that $\bigcup$(the sorts of A) is non empty.

Let S be a non empty non void many sorted signature and let A be a non empty algebra over S. An element of A is an element of $\bigcup$(the sorts of A).

One can prove the following two propositions:

(1) For every function f such that $X \subseteq \mathrm{dom}\, f$ and f is one-to-one holds $f^{-1}(f^\circ X) = X$.

(2) Let I be a set, A be a many sorted set indexed by I, and F be a many sorted function indexed by I. If F is "1-1" and $A \subseteq \mathrm{dom}_\kappa F(\kappa)$, then $F^{-1}(F \circ A) = A$.

Let S be a non void signature and let X be a many sorted set indexed by the carrier of S. The functor $\mathrm{Free}_S(X)$ yielding a strict algebra over S is defined by:

(Def. 2)[1] There exists a subset A of Free($X \cup$ ((the carrier of S) $\longmapsto \{0\}$)) such that $\mathrm{Free}_S(X) =$ Gen(A) and $A =$ (Reverse($X \cup$ ((the carrier of S) $\longmapsto \{0\}$)))$^{-1}(X)$.

The following propositions are true:

(3) Let S be a non void signature, X be a non-empty many sorted set indexed by the carrier of S, and s be a sort symbol of S. Then $\langle x, s \rangle \in$ the carrier of DTConMSA(X) if and only if $x \in X(s)$.

(4) Let S be a non void signature, Y be a non-empty many sorted set indexed by the carrier of S, X be a many sorted set indexed by the carrier of S, and s be a sort symbol of S. Then $x \in X(s)$ and $x \in Y(s)$ if and only if the root tree of $\langle x, s \rangle \in$ ((Reverse(Y))$^{-1}(X)$)(s).

(5) Let S be a non void signature, X be a many sorted set indexed by the carrier of S, and s be a sort symbol of S. If $x \in X(s)$, then the root tree of $\langle x, s \rangle \in$ (the sorts of $\mathrm{Free}_S(X)$)(s).

(6) Let S be a non void signature, X be a many sorted set indexed by the carrier of S, and o be an operation symbol of S. Suppose Arity(o) $= \emptyset$. Then the root tree of $\langle o$, the carrier of $S \rangle \in$ (the sorts of $\mathrm{Free}_S(X)$)(the result sort of o).

[1] The definition (Def. 1) has been removed.

Let S be a non void signature and let X be a non empty yielding many sorted set indexed by the carrier of S. Observe that $\mathrm{Free}_S(X)$ is non empty.

Next we state three propositions:

(7) Let S be a non void signature and X be a non-empty many sorted set indexed by the carrier of S. Then x is an element of $\mathrm{Free}(X)$ if and only if x is a term of S over X.

(8) Let S be a non void signature, X be a non-empty many sorted set indexed by the carrier of S, s be a sort symbol of S, and x be a term of S over X. Then $x \in$ (the sorts of $\mathrm{Free}(X))(s)$ if and only if the sort of $x = s$.

(9) Let S be a non void signature and X be a non empty yielding many sorted set indexed by the carrier of S. Then every element of $\mathrm{Free}_S(X)$ is a term of S over $X \cup$ ((the carrier of $S) \longmapsto \{0\})$.

Let S be a non empty non void many sorted signature and let X be a non empty yielding many sorted set indexed by the carrier of S. One can verify that every element of $\mathrm{Free}_S(X)$ is relation-like and function-like.

Let S be a non empty non void many sorted signature and let X be a non empty yielding many sorted set indexed by the carrier of S. One can check that every element of $\mathrm{Free}_S(X)$ is finite and decorated tree-like.

Let S be a non empty non void many sorted signature and let X be a non empty yielding many sorted set indexed by the carrier of S. One can verify that every element of $\mathrm{Free}_S(X)$ is finite-branching.

Let us note that every decorated tree is non empty.

Let S be a many sorted signature and let t be a non empty binary relation. The functor $\mathrm{Var}_S t$ yielding a many sorted set indexed by the carrier of S is defined as follows:

(Def. 3) For every set s such that $s \in$ the carrier of S holds $(\mathrm{Var}_S t)(s) = \{a_{\mathbf{1}}; a$ ranges over elements of $\mathrm{rng}\, t : a_{\mathbf{2}} = s\}$.

Let S be a many sorted signature, let X be a many sorted set indexed by the carrier of S, and let t be a non empty binary relation. The functor $\mathrm{Var}_X t$ yields a many sorted subset indexed by X and is defined as follows:

(Def. 4) $\mathrm{Var}_X t = X \cap \mathrm{Var}_S t$.

We now state several propositions:

(10) Let S be a many sorted signature, X be a many sorted set indexed by the carrier of S, t be a non empty binary relation, and V be a many sorted subset indexed by X. Then $V = \mathrm{Var}_X t$ if and only if for every set s such that $s \in$ the carrier of S holds $V(s) = X(s) \cap \{a_{\mathbf{1}}; a$ ranges over elements of $\mathrm{rng}\, t : a_{\mathbf{2}} = s\}$.

(11) Let S be a many sorted signature and s, x be sets. Then

(i) if $s \in$ the carrier of S, then $(\mathrm{Var}_S$(the root tree of $\langle x, s\rangle))(s) = \{x\}$, and

(ii) for every set s' such that $s' \neq s$ or $s \notin$ the carrier of S holds $(\mathrm{Var}_S$(the root tree of $\langle x, s\rangle))(s') = \emptyset$.

(12) Let S be a many sorted signature and s be a set. Suppose $s \in$ the carrier of S. Let p be a decorated tree yielding finite sequence. Then $x \in (\mathrm{Var}_S(\langle z$, the carrier of $S\rangle$-tree$(p)))(s)$ if and only if there exists a decorated tree t such that $t \in \mathrm{rng}\, p$ and $x \in (\mathrm{Var}_S t)(s)$.

(13) Let S be a many sorted signature, X be a many sorted set indexed by the carrier of S, and s, x be sets. Then

(i) if $x \in X(s)$, then $(\mathrm{Var}_X$(the root tree of $\langle x, s\rangle))(s) = \{x\}$, and

(ii) for every set s' such that $s' \neq s$ or $x \notin X(s)$ holds $(\mathrm{Var}_X$(the root tree of $\langle x, s\rangle))(s') = \emptyset$.

(14) Let S be a many sorted signature, X be a many sorted set indexed by the carrier of S, and s be a set. Suppose $s \in$ the carrier of S. Let p be a decorated tree yielding finite sequence. Then $x \in (\mathrm{Var}_X(\langle z, \text{the carrier of } S\rangle\text{-tree}(p)))(s)$ if and only if there exists a decorated tree t such that $t \in \mathrm{rng}\, p$ and $x \in (\mathrm{Var}_X t)(s)$.

(15) Let S be a non void signature, X be a non-empty many sorted set indexed by the carrier of S, and t be a term of S over X. Then $\mathrm{Var}_S t \subseteq X$.

Let S be a non void signature, let X be a non-empty many sorted set indexed by the carrier of S, and let t be a term of S over X. The functor Var_t yields a many sorted subset indexed by X and is defined by:

(Def. 5) $\mathrm{Var}_t = \mathrm{Var}_S t$.

We now state the proposition

(16) Let S be a non void signature, X be a non-empty many sorted set indexed by the carrier of S, and t be a term of S over X. Then $\mathrm{Var}_t = \mathrm{Var}_X t$.

Let S be a non void signature, let Y be a non-empty many sorted set indexed by the carrier of S, and let X be a many sorted set indexed by the carrier of S. The functor $S\text{-Terms}^Y(X)$ yielding a subset of $\mathrm{Free}(Y)$ is defined by:

(Def. 6) For every sort symbol s of S holds $(S\text{-Terms}^Y(X))(s) = \{t; t$ ranges over terms of S over Y: the sort of $t = s \wedge \mathrm{Var}_t \subseteq X\}$.

One can prove the following propositions:

(17) Let S be a non void signature, Y be a non-empty many sorted set indexed by the carrier of S, X be a many sorted set indexed by the carrier of S, and s be a sort symbol of S. If $x \in (S\text{-Terms}^Y(X))(s)$, then x is a term of S over Y.

(18) Let S be a non void signature, Y be a non-empty many sorted set indexed by the carrier of S, X be a many sorted set indexed by the carrier of S, t be a term of S over Y, and s be a sort symbol of S. If $t \in (S\text{-Terms}^Y(X))(s)$, then the sort of $t = s$ and $\mathrm{Var}_t \subseteq X$.

(19) Let S be a non void signature, Y be a non-empty many sorted set indexed by the carrier of S, X be a many sorted set indexed by the carrier of S, and s be a sort symbol of S. Then the root tree of $\langle x, s\rangle \in (S\text{-Terms}^Y(X))(s)$ if and only if $x \in X(s)$ and $x \in Y(s)$.

(20) Let S be a non void signature, Y be a non-empty many sorted set indexed by the carrier of S, X be a many sorted set indexed by the carrier of S, o be an operation symbol of S, and p be an argument sequence of $\mathrm{Sym}(o,Y)$. Then $\mathrm{Sym}(o,Y)\text{-tree}(p) \in (S\text{-Terms}^Y(X))(\text{the result sort of } o)$ if and only if $\mathrm{rng}\, p \subseteq \bigcup (S\text{-Terms}^Y(X))$.

(21) Let S be a non void signature, X be a non-empty many sorted set indexed by the carrier of S, and A be a subset of $\mathrm{Free}(X)$. Then A is operations closed if and only if for every operation symbol o of S and for every argument sequence p of $\mathrm{Sym}(o,X)$ such that $\mathrm{rng}\, p \subseteq \bigcup A$ holds $\mathrm{Sym}(o,X)\text{-tree}(p) \in A(\text{the result sort of } o)$.

(22) Let S be a non void signature, Y be a non-empty many sorted set indexed by the carrier of S, and X be a many sorted set indexed by the carrier of S. Then $S\text{-Terms}^Y(X)$ is operations closed.

(23) Let S be a non void signature, Y be a non-empty many sorted set indexed by the carrier of S, and X be a many sorted set indexed by the carrier of S. Then $(\mathrm{Reverse}(Y))^{-1}(X) \subseteq S\text{-Terms}^Y(X)$.

(24) Let S be a non void signature, X be a many sorted set indexed by the carrier of S, t be a term of S over $X \cup ((\text{the carrier of } S) \longmapsto \{0\})$, and s be a sort symbol of S. If $t \in (S\text{-Terms}^{X \cup ((\text{the carrier of } S) \longmapsto \{0\})}(X))(s)$, then $t \in (\text{the sorts of } \mathrm{Free}_S(X))(s)$.

(25) Let S be a non void signature and X be a many sorted set indexed by the carrier of S. Then the sorts of $\mathrm{Free}_S(X) = S\text{-Terms}^{X\cup((\text{the carrier of } S)\longmapsto\{0\})}(X)$.

(26) Let S be a non void signature and X be a many sorted set indexed by the carrier of S. Then $\mathrm{Free}(X \cup ((\text{the carrier of } S) \longmapsto \{0\}))\restriction(S\text{-Terms}^{X\cup((\text{the carrier of } S)\longmapsto\{0\})}(X)) = \mathrm{Free}_S(X)$.

(27) Let S be a non void signature, X, Y be non-empty many sorted sets indexed by the carrier of S, A be a subalgebra of $\mathrm{Free}(X)$, and B be a subalgebra of $\mathrm{Free}(Y)$. Suppose the sorts of $A =$ the sorts of B. Then the algebra of $A =$ the algebra of B.

(28) Let S be a non void signature, X be a non empty yielding many sorted set indexed by the carrier of S, Y be a many sorted set indexed by the carrier of S, and t be an element of $\mathrm{Free}_S(X)$. Then $\mathrm{Var}_S\, t \subseteq X$.

(29) Let S be a non void signature, X be a non-empty many sorted set indexed by the carrier of S, and t be a term of S over X. Then $\mathrm{Var}_t \subseteq X$.

(30) Let S be a non void signature, X, Y be non-empty many sorted sets indexed by the carrier of S, t_1 be a term of S over X, and t_2 be a term of S over Y. If $t_1 = t_2$, then the sort of $t_1 =$ the sort of t_2.

(31) Let S be a non void signature, X, Y be non-empty many sorted sets indexed by the carrier of S, and t be a term of S over Y. If $\mathrm{Var}_t \subseteq X$, then t is a term of S over X.

(32) Let S be a non void signature and X be a non-empty many sorted set indexed by the carrier of S. Then $\mathrm{Free}_S(X) = \mathrm{Free}(X)$.

(33) Let S be a non void signature, Y be a non-empty many sorted set indexed by the carrier of S, t be a term of S over Y, and p be an element of $\mathrm{dom}\, t$. Then $\mathrm{Var}_{t\restriction p} \subseteq \mathrm{Var}_t$.

(34) Let S be a non void signature, X be a non empty yielding many sorted set indexed by the carrier of S, t be an element of $\mathrm{Free}_S(X)$, and p be an element of $\mathrm{dom}\, t$. Then $t\restriction p$ is an element of $\mathrm{Free}_S(X)$.

(35) Let S be a non void signature, X be a non-empty many sorted set indexed by the carrier of S, t be a term of S over X, and a be an element of $\mathrm{rng}\, t$. Then $a = \langle a_{\mathbf{1}}, a_{\mathbf{2}} \rangle$.

(36) Let S be a non void signature, X be a non empty yielding many sorted set indexed by the carrier of S, t be an element of $\mathrm{Free}_S(X)$, and s be a sort symbol of S. Then

(i) if $x \in (\mathrm{Var}_S\, t)(s)$, then $\langle x, s \rangle \in \mathrm{rng}\, t$, and

(ii) if $\langle x, s \rangle \in \mathrm{rng}\, t$, then $x \in (\mathrm{Var}_S\, t)(s)$ and $x \in X(s)$.

(37) Let S be a non void signature and X be a many sorted set indexed by the carrier of S. Suppose that for every sort symbol s of S such that $X(s) = \emptyset$ there exists an operation symbol o of S such that the result sort of $o = s$ and $\mathrm{Arity}(o) = \emptyset$. Then $\mathrm{Free}_S(X)$ is non-empty.

(38) Let S be a non void non empty many sorted signature, A be an algebra over S, B be a subalgebra of A, and o be an operation symbol of S. Then $\mathrm{Args}(o,B) \subseteq \mathrm{Args}(o,A)$.

(39) For every non void signature S and for every feasible algebra A over S holds every subalgebra of A is feasible.

Let S be a non void signature and let A be a feasible algebra over S. Note that every subalgebra of A is feasible.

We now state the proposition

(40) Let S be a non void signature and X be a many sorted set indexed by the carrier of S. Then $\mathrm{Free}_S(X)$ is feasible and free.

Let S be a non void signature and let X be a many sorted set indexed by the carrier of S. One can check that $\mathrm{Free}_S(X)$ is feasible and free.

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Received August 8, 2001

Published January 2, 2004