

Semantics of MML Query - Ordering

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Summary. Semantics of order directives of MML Query is presented. The formalization is done according to [1].

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The notation and terminology used in this paper have been introduced in the following articles: [2], [7], [13], [9], [10], [8], [3], [4], [5], [11], [17], [19], [18], [6], [15], [16], [14], and [12].

1. PRELIMINARIES

In this paper X denotes a set, R, R_1, R_2 denote binary relations, x, y, z denote sets, and n, m, k denote natural numbers.

Let us consider a binary relation R on X . Now we state the propositions:

- (1) field $R \subseteq X$.
- (2) If $x, y \in R$, then $x, y \in X$.

Now we state the propositions:

- (3) Let us consider sets X, Y . Then $(\text{id}_X)^\circ Y = X \cap Y$.
- (4) $\langle x, y \rangle \in R \mid^2 X$ if and only if $x, y \in X$ and $\langle x, y \rangle \in R$.
- (5) $\text{dom}(X \upharpoonright R) \subseteq \text{dom } R$.
- (6) Let us consider a total reflexive binary relation R on X and a subset S of X . Then $R \mid^2 S$ is a total reflexive binary relation on S . The theorem is a consequence of (4). PROOF: Set $Q = R \mid^2 S$. $\text{dom } Q = S$. \square
- (7) Let us consider transfinite sequences f, g . Then $\text{rng}(f \hat{\ } g) = \text{rng } f \cup \text{rng } g$.

Let us consider R . Let us note that R is transitive if and only if the condition (Def. 1) is satisfied.

(Def. 1) If $x, y \in R$ and $y, z \in R$, then $x, z \in R$.

One can verify that R is antisymmetric if and only if the condition (Def. 2) is satisfied.

(Def. 2) If $x, y \in R$ and $y, x \in R$, then $x = y$.

Now we state the proposition:

(8) Let us consider a non empty set X , a total connected binary relation R on X , and elements x, y of X . If $x \neq y$, then $x, y \in R$ or $y, x \in R$.

2. COMPOSITION OF ORDERS

Let R_1, R_2 be binary relations. The functor R_1, R_2 yielding a binary relation is defined by the term

(Def. 3) $R_1 \cup (R_2 \setminus R_1 \smile)$.

Now we state the propositions:

(9) $x, y \in R_1, R_2$ if and only if $x, y \in R_1$ or $y, x \notin R_1$ and $x, y \in R_2$.

(10) $\text{field}(R_1, R_2) = \text{field } R_1 \cup \text{field } R_2$. The theorem is a consequence of (9).

(11) $R_1, R_2 \subseteq R_1 \cup R_2$. The theorem is a consequence of (9).

Let X be a set and R_1, R_2 be binary relations on X . Note that the functor R_1, R_2 yields a binary relation on X . Let R_1, R_2 be reflexive binary relations. One can verify that R_1, R_2 is reflexive.

Let R_1, R_2 be antisymmetric binary relations. Note that R_1, R_2 is antisymmetric.

Let X be a set and R be a binary relation on X . We say that R is β -transitive if and only if

(Def. 4) Let us consider elements x, y of X . If $x, y \notin R$, then for every element z of X such that $x, z \in R$ holds $y, z \in R$.

Observe that every binary relation on X which is connected total and transitive is also β -transitive.

Let us observe that there exists an order in X which is connected.

Let R_1 be a β -transitive transitive binary relation on X and R_2 be a transitive binary relation on X . Observe that R_1, R_2 is transitive.

Let R_1 be a binary relation on X and R_2 be a total reflexive binary relation on X . Let us note that R_1, R_2 is total and reflexive as a binary relation on X .

Let R_2 be a total connected reflexive binary relation on X . One can verify that R_1, R_2 is connected.

Now we state the propositions:

(12) $(R, R_1), R_2 = R, (R_1, R_2)$. The theorem is a consequence of (9).

(13) Let us consider a connected reflexive total binary relation R on X and a binary relation R_2 on X . Then $R, R_2 = R$. The theorem is a consequence of (9) and (2).

3. number of ORDERING

Let X be a set and f be a function from X into \mathbb{N} . The functor **number of** f yielding a binary relation on X is defined by

(Def. 5) $x, y \in it$ if and only if $x, y \in X$ and $f(x) < f(y)$.

Let us note that **number of** f is antisymmetric transitive and β -transitive.

Let X be a finite set and O be an operation of X . The functor **value of** O yielding a function from X into \mathbb{N} is defined by

(Def. 6) Let us consider an element x of X . Then $it(x) = \overline{\overline{x(O)}}$.

Now we state the proposition:

(14) Let us consider a finite set X , an operation O of X , and elements x, y of X . Then $x, y \in \text{number of value of } O$ if and only if $\overline{\overline{x(O)}} < \overline{\overline{y(O)}}$.

Let us consider X . Let O be an operation of X . The functor **first** O yielding a binary relation on X is defined by

(Def. 7) Let us consider elements x, y of X . Then $x, y \in it$ if and only if $x(O) \neq \emptyset$ and $y(O) = \emptyset$.

Let us observe that **first** O is antisymmetric transitive and β -transitive.

4. ORDERING BY RESOURCES

Let A be a finite sequence and x be an element. The functor $A \leftarrow x$ yielding a set is defined by the term

(Def. 8) $\bigcap(A^{-1}(\{x\}))$.

Let us consider x . Note that $A \leftarrow x$ is natural.

Let us consider a finite sequence A . Now we state the propositions:

(15) If $x \notin \text{rng } A$, then $A \leftarrow x = 0$.

(16) If $x \in \text{rng } A$, then $A \leftarrow x \in \text{dom } A$ and $x = A(A \leftarrow x)$.

(17) If $A \leftarrow x = 0$, then $x \notin \text{rng } A$.

Let us consider X . Let A be a finite sequence and f be a function. The functor **resource**(X, A, f) yielding a binary relation on X is defined by

(Def. 9) $x, y \in it$ if and only if $x, y \in X$ and $A \leftarrow (f(x)) \neq 0$ and $A \leftarrow (f(x)) < A \leftarrow (f(y))$ or $A \leftarrow (f(y)) = 0$.

Let us observe that **resource**(X, A, f) is antisymmetric transitive and β -transitive.

5. ORDERING BY NUMBER OF ITERATION

Let us consider X . Let R be a binary relation on X and n be a natural number. One can check that the functor R^n yields a binary relation on X . Now we state the propositions:

- (18) If $(R^n)^\circ X = \emptyset$ and $m \geq n$, then $(R^m)^\circ X = \emptyset$.
- (19) If for every n , $(R^n)^\circ X \neq \emptyset$ and X is finite, then there exists x such that $x \in X$ and for every n , $(R^n)^\circ x \neq \emptyset$. The theorem is a consequence of (18).
 PROOF: Define $\mathcal{P}[\text{element, element}] \equiv$ there exists n such that $\$2 = n$ and $(R^n)^\circ \$1 = \emptyset$. For every element x such that $x \in X$ there exists an element y such that $y \in \mathbb{N}$ and $\mathcal{P}[x, y]$. Consider f being a function such that $\text{dom } f = X$ and $\text{rng } f \subseteq \mathbb{N}$ and for every element x such that $x \in X$ holds $\mathcal{P}[x, f(x)]$. Consider n such that $\text{rng } f \subseteq \mathbb{Z}_n$. $\{\{x\} \text{ where } x \text{ is an element of } X : x \in X\} \subseteq 2^X$. Reconsider $Y = \{\{x\} \text{ where } x \text{ is an element of } X : x \in X\}$ as a family of subsets of X . $X = \bigcup Y$. $\{(R^n)^\circ y \text{ where } y \text{ is a subset of } X : y \in Y\} \subseteq \{\emptyset\}$. \square
- (20) If R is reversely well founded and irreflexive and X is finite and R is finite, then there exists n such that $(R^n)^\circ X = \emptyset$. The theorem is a consequence of (19).
 PROOF: Define $\mathcal{Q}[\text{element}] \equiv$ for every n , $(R^n)^\circ \$1 \neq \emptyset$. Consider $x0$ being a set such that $x0 \in X$ and $\mathcal{Q}[x0]$. Define $\mathcal{P}[\text{element, element, element}] \equiv$ if $\mathcal{Q}[\$2]$, then $\$3 \in R^\circ \2 and $\mathcal{Q}[\$3]$. For every natural number n and for every set x , there exists a set y such that $\mathcal{P}[n, x, y]$. Consider f being a function such that $\text{dom } f = \mathbb{N}$ and $f(0) = x0$ and for every natural number n , $\mathcal{P}[n, f(n), f(n+1)]$. Define $\mathcal{R}[\text{natural number}] \equiv \mathcal{Q}[f(\$1)]$. $\text{rng } f \subseteq \text{field } R$. Consider z being an element such that $z \in \text{rng } f$ and for every element x such that $x \in \text{rng } f$ and $z \neq x$ holds $\langle z, x \rangle \notin R$. Consider y being an element such that $y \in \mathbb{N}$ and $z = f(y)$. \square

Let us consider X . Let O be an operation of X . Assume O is reversely well founded, irreflexive, and finite. The functor **iteration of** O yielding a binary relation on X is defined by

(Def. 10) There exists a function f from X into \mathbb{N} such that

- (i) $it = \text{number of } f$, and
- (ii) for every element x of X such that $x \in X$ there exists n such that $f(x) = n$ and $x(O^n) \neq \emptyset$ or $n = 0$ and $x(O^n) = \emptyset$ and $x(O^{n+1}) = \emptyset$.

Let us note that every binary relation which is empty is also irreflexive and reversely well founded.

Let us consider X . Let us note that there exists an operation of X which is empty.

Let O be a reversely well founded irreflexive finite operation of X . One can check that **iteration of** O is antisymmetric transitive and β -transitive.

6. value of ORDERING

Let X be a finite set. Let us observe that every order in X is well founded.

Note that every connected order in X is well-ordering.

Let us consider X . Let R be a connected order in X and S be a finite subset of X . The functor $\text{order}(S, R)$ yielding a finite 0-sequence of X is defined by

- (Def. 11) (i) $\text{rng } it = S$, and
 (ii) it is one-to-one, and
 (iii) for every natural numbers i, j such that $i, j \in \text{dom } it$ holds $i \leq j$ iff $it(i), it(j) \in R$.

Now we state the proposition:

- (21) Let us consider finite subsets S_1, S_2 of X and a connected order R in X . Then $\text{order}(S_1 \cup S_2, R) = \text{order}(S_1, R) \cap \text{order}(S_2, R)$ if and only if for every x and y such that $x \in S_1$ and $y \in S_2$ holds $x \neq y$ and $x, y \in R$. The theorem is a consequence of (7). PROOF: Set $o1 = \text{order}(S_1, R)$. Set $o2 = \text{order}(S_2, R)$. $\text{order}(S_1, R) \cap \text{order}(S_2, R)$ is one-to-one. \square

Let X be a finite set, O be an operation of X , and R be a connected order in X . The functor $\text{value of}(O, R)$ yielding a binary relation on X is defined by

- (Def. 12) Let us consider elements x, y of X . Then $x, y \in it$ if and only if $x(O) \neq \emptyset$ and $y(O) = \emptyset$ or $y(O) \neq \emptyset$ and $(\text{order}(x(O), R))_0, (\text{order}(y(O), R))_0 \in R$ and $(\text{order}(x(O), R))_0 \neq (\text{order}(y(O), R))_0$.

Let R_1 be a connected order in X . One can check that $\text{value of}(O, R_1)$ is antisymmetric transitive and β -transitive.

REFERENCES

- [1] Grzegorz Bancerek. Information retrieval and rendering with MML query. *LNCS*, 4108: 266–279, 2006.
- [2] Grzegorz Bancerek. Cardinal numbers. *Formalized Mathematics*, 1(2):377–382, 1990.
- [3] Grzegorz Bancerek. Semantics of MML query. *Formalized Mathematics*, 20(2):147–155, 2012. doi:10.2478/v10037-012-0017-x.
- [4] Grzegorz Bancerek. The ordinal numbers. *Formalized Mathematics*, 1(1):91–96, 1990.
- [5] Grzegorz Bancerek. Increasing and continuous ordinal sequences. *Formalized Mathematics*, 1(4):711–714, 1990.
- [6] Grzegorz Bancerek. Reduction relations. *Formalized Mathematics*, 5(4):469–478, 1996.
- [7] Grzegorz Bancerek and Krzysztof Hryniewiecki. Segments of natural numbers and finite sequences. *Formalized Mathematics*, 1(1):107–114, 1990.
- [8] Grzegorz Bancerek and Andrzej Trybulec. Miscellaneous facts about functions. *Formalized Mathematics*, 5(4):485–492, 1996.
- [9] Czesław Byliński. Functions and their basic properties. *Formalized Mathematics*, 1(1): 55–65, 1990.
- [10] Czesław Byliński. Functions from a set to a set. *Formalized Mathematics*, 1(1):153–164, 1990.
- [11] Czesław Byliński. Partial functions. *Formalized Mathematics*, 1(2):357–367, 1990.
- [12] Czesław Byliński. Some basic properties of sets. *Formalized Mathematics*, 1(1):47–53, 1990.

- [13] Agata Darmochwał. Finite sets. *Formalized Mathematics*, 1(1):165–167, 1990.
- [14] Krzysztof Hryniewiecki. Relations of tolerance. *Formalized Mathematics*, 2(1):105–109, 1991.
- [15] Beata Padlewska. Families of sets. *Formalized Mathematics*, 1(1):147–152, 1990.
- [16] Zinaida Trybulec. Properties of subsets. *Formalized Mathematics*, 1(1):67–71, 1990.
- [17] Edmund Woronowicz. Relations and their basic properties. *Formalized Mathematics*, 1(1):73–83, 1990.
- [18] Edmund Woronowicz. Relations defined on sets. *Formalized Mathematics*, 1(1):181–186, 1990.
- [19] Edmund Woronowicz and Anna Zalewska. Properties of binary relations. *Formalized Mathematics*, 1(1):85–89, 1990.

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