

What is claimed is:

1. A computing system including:

a data storage system storing entity data representing a plurality of entities that are related according to a hierarchy, where at least one root entity is at a highest level of the hierarchy and one or more entities are at one or more levels below the highest level of the hierarchy, each entity at a level lower than the root entity is a child entity of a single entity, and the one or more entities each have: multiple instances, and at least one attribute that has respective elements for each of the instances;

an input device or port for receiving input data that includes one or more expressions that each express one or more functions of one or more arguments, with one or more of the arguments referencing an attribute of an entity represented in the entity data; and

at least one processor configured to process the expressions included in the input data, the processing including:

analyzing an expression to determine, for each of one or more attributes referenced by an argument of the expression, at least one of: (1) a position in the hierarchy of an entity of the attribute, or (2) a number of elements of a result of a function applied to an argument that references the attribute, and

evaluating the expression, or indicating an error based on a result of analyzing the expression;

wherein said determining a position in the hierarchy of an entity of the attribute includes determining context for the attribute based on a path to the entity of the attribute through a chain of entities related by parent-child relationships starting from the root entity;

and wherein analyzing the expression further includes performing a promotion procedure that includes, for at least a first attribute of at least a first corresponding entity referenced by an argument of the expression, promoting a context of a second attribute of an entity that is an ancestor of the at least the first corresponding entity, where the second attribute is referenced by an argument of the expression, and where promoting the context of the second attribute includes replacing the context of the second attribute with the context of the first attribute.

2. The computing system of claim 1, wherein the input data includes a first expression that defines values of one or more elements of a first attribute of a first entity represented in the entity data.

3. The computing system of claim 2, wherein the first expression defines the values of one or more elements of the first attribute with reference to a second attribute of a second entity represented in the entity data.

4. The computing system of claim 3, wherein the computing system includes a transaction processing system.

5. The computing system of claim 4, wherein the first entity has instances that correspond to different purchases in the transaction processing system, and the second entity has instances that correspond to different customers in the transaction processing system.

6. The computing system of claim 2, wherein the processing further includes updating the entity data to represent the values of one or more elements of the first attribute, after evaluating the first expression.

7. The computing system of claim 1, wherein at least one function in at least one expression includes one or more operators operating on two or more operands, with two or more of the operands referencing an attribute of an entity represented by the stored data.

8. The computing system of claim 7, wherein analyzing the expression further includes determining that the referenced attributes include only one vector-valued referenced attribute and one or more scalar-valued referenced attributes, and evaluating the expression includes replicating the scalar-valued referenced attribute for every element of the vector-valued referenced attribute.

9. The computing system of claim 7, wherein analyzing the expression further includes: determining that the referenced attributes include multiple vector-valued referenced attributes, and comparing respective positions in the hierarchy of two or more of the vector-valued referenced attributes.

10. The computing system of claim 7, wherein the processing includes indicating an error based on two or more of vector-valued referenced attributes having different respective positions in the hierarchy.

11. The computing system of claim 1, wherein the processing includes indicating an error based on a first attribute referenced by a first argument of a first expression having a different context from a second attribute referenced by a second argument of the first expression.

12. The computing system of claim 1, wherein analyzing the expression includes determining, for each of two or more attributes referenced by respective arguments, a position in the hierarchy of an entity of the attribute.

13. The computing system of claim 12, wherein analyzing the expression includes comparing the determined positions, and indicating an error in response to an incompatibility between at least two of the determined positions with respect to a function being applied to their respective arguments.

14. The computing system of claim 1, wherein analyzing the expression includes determining, for each of one or more attributes referenced by an argument, a number of elements of a result of a function applied to an argument that references the attribute.

15. The computing system of claim 14, wherein analyzing the expression includes determining, for at least a first attribute referenced by an argument of an aggregation function, a number of elements of a result of the aggregation function, and in response to the result not corresponding to a scalar value with respect to an entity of the first attribute, repeating application of the aggregation function one or more times until a result corresponds to a scalar value with respect to the entity of the first attribute.

16. A method including:

storing, in a data storage system, entity data representing a plurality of entities that are related according to a hierarchy, where at least one root entity is at a highest level of the hierarchy and one or more entities are at one or more levels below the highest level of the hierarchy, each entity at a level lower than the root entity is a child entity of a single entity, and one or more entities each have: multiple instances, and at least one attribute that has respective elements for each of the instances;

receiving, over an input device or port, input data that includes one or more expressions that each express one or more functions of one or more arguments, with one or more of the arguments referencing an attribute of an entity represented in the entity data; and

processing, using at least one processor, the expressions included in the input data, the processing including:

analyzing an expression to determine, for each of one or more attributes referenced by an argument of the expression, at least one of: (1) a position in the hierarchy of an entity of the attribute, or (2) a number of elements of a result of a function applied to an argument that references the attribute, and

evaluating the expression, or indicating an error based on a result of analyzing the expression;

wherein said determining a position in the hierarchy of an entity of the attribute includes determining context for the attribute based on a path to the entity of the attribute through a chain of entities related by parent-child relationships starting from the root entity;

and wherein analyzing the expression further includes performing a promotion procedure that includes, for at least a first attribute of at least a first corresponding entity referenced by an argument of the expression, promoting a context of a second attribute of an entity that is an ancestor of the at least the first corresponding entity, where the second attribute is referenced by an argument of the expression, and where promoting the context of the second attribute includes replacing the context of the second attribute with the context of the first attribute.

17. Software stored in a non-transitory form on a computer-readable medium, the software including instructions for causing a computing system to:

store, in a data storage system, entity data representing a plurality of entities that are related according to a hierarchy, where at least one root entity is at a highest level of the hierarchy and one or more entities are at one or more levels below the highest level of the hierarchy, each entity at a level lower than the root entity is a child entity of a single entity, and the one or more entities each have: multiple instances, and at least one attribute that has respective elements for each of the instances;

receive, over an input device or port, input data that includes one or more expressions that each express one or more functions of one or more arguments, with one or more of the arguments referencing an attribute of an entity represented in the entity data; and

process, using at least one processor, the expressions included in the input data, the processing including:

analyzing an expression to determine, for each of one or more attributes referenced by an argument of the expression, at least one of: (1) a position in the hierarchy of an entity of the attribute, or (2) a number of elements of a result of a function applied to an argument that references the attribute, and

evaluating the expression, or indicating an error based on a result of analyzing the expression;

wherein said determining a position in the hierarchy of an entity of the attribute includes determining context for the attribute based on a path to the entity of the attribute through a chain of entities related by parent-child relationships starting from the root entity;

and wherein analyzing the expression further includes performing a promotion procedure that includes, for at least a first attribute of at least a first corresponding entity referenced by an argument of the expression, promoting a context of a second attribute of an entity that is an ancestor of the at least the first corresponding entity, where the second attribute is referenced by an argument of the expression, and where promoting the context of the second attribute includes replacing the context of the second attribute with the context of the first attribute.

18. The computing system of claim 1, wherein analyzing the expression further includes determining, when the expression includes two or more attributes, whether each pair of the two or more attributes are conformable, wherein a pair of attributes are determined to be conformable when an operation within the expression applied to the pair of attributes does not result in an expression error.

19. The computing system of claim 18, wherein determining whether each pair of the two or more attributes are conformable includes:

determining whether one context of one attribute of the each pair of the two or more attributes is identical to another context of another attribute of the each pair of the two or more attributes, or determining whether the one context of the one attribute is a prefix of the other context of the other attribute, wherein the one context defines an entity path between a root entity of the hierarchy to the one attribute to represent a first position of the one attribute in the hierarchy, and the other context defines another entity path between the root entity to the other attribute to represent another position of the other attribute in the hierarchy.

20. The computing system of claim 18, wherein determining whether each pair of the two or more attributes are conformable includes:

determining, in response to a first determination that a first attribute and a second attribute of a pair of attributes are vectors, whether a vector operation within the expression applied to the first and second vector attributes does not result in a vector-operation error.