OneToMany (Set) bi-directional (and ManyToOne) test on persistent instances

→+ Cascaded link

∞ Non-cascaded backRef link

Sets are represented as elements within curly braces. Maps have keys before the elements separated with a “:” delimiter. Lists have numbers before the elements separated with a “.” delimiter. The →+ or the →- operators also updates the key (for map) and index (for list) respectively if necessary. TODO: check if each action is independent and does not make any assumptions, if it is not independent then convert it to an incomplete action.

Consideration for a bi-directional relationship

The only time the ManyToOne side of a bi-directional relationship needs to be evaluated is if it has a MapKey or a ListIndex mapping. Otherwise it constitutes an error if the OneToMany side is not present (this is identified by when processing the actions).

If the MapKey or ListIndex mapping is present, there is some missing information, since for a List or Map, there are multiple possibilities:

* The value at the current index needs to be replaced
* The value at the current index needs to be inserted
* The map key for an existing value needs to be updated
* An additional map key points to the same value

If a ListIndex or MapKey is provided then we cannot allow duplicates in the List nor have multiple keys point to the same value.

In a bi-directional relationship the ManyToOne side will generate an incomplete Element Action that will be corrected by the action generated by the OneToMany side. If the index or key is tracked by the element then it cannot be an incomplete action, since the incomplete information is related to the position.

Introducing an unchanged operation Xx= will help to detect additional conflicts. But this creates additional actions to process. This behavior can be controlled through configuration.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **#** | **A** | | | | **B** | | | | **C** | | | | **D** | | | | **A** | **B** | **C** | **D** |
| ***Old*** | | ***New*** | | ***Old*** | | ***New*** | | ***Old*** | | ***New*** | | ***Old*** | | ***New*** | |  |  |  |  |
| **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** |  |  |  |  |
| 1 |  | {∅} |  | {B} | ∅ |  | A |  |  |  |  |  |  |  |  |  | AA →+ B  AB →+ B | BA ∞ A  BB ∞ A |  |  |
| 2 |  | {∅} |  | {B} | ∅ |  | ∅ |  |  |  |  |  |  |  |  |  | AA →+ B | BA ∞ A |  |  |
| 3 |  | {∅} |  | {B, C} | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | AA →+ B  AA →+ C  AB →+ B  AC →+ C | BA ∞ A  BB ∞ A | CA ∞ A  CC ∞ A |  |
| 4 |  | {C} |  | {B} | ∅ |  | A |  | A |  | ∅ |  |  |  |  |  | AA →- C  AA →+ B  AB →+ B  AC →- C | BA ∞ A  BB ∞ A | CA ∞ ∅  CC ∞ ∅ |  |
| 5 |  | {C} |  | {B} | ∅ |  | ∅ |  | A |  | ∅ |  |  |  |  |  | AA →- C  AA →+ B  AC →- C | BA ∞ A | CA ∞ ∅  CC ∞ ∅ |  |
| 6 |  | {∅} |  | {B} | C |  | A |  |  | {B} |  | {∅} |  |  |  |  | AA →+ B  AB →+ B | BA ∞ A  BB ∞ A  ~~B~~~~C~~ ∞ ~~∅~~ | CB →- B  CC →- B |  |
| 7 |  | {∅} |  | {B} | C |  | ∅ |  |  | {B} |  | {∅} |  |  |  |  | AA →+ B | BA ∞ A  BB ∞ ~~∅~~  ~~B~~~~C~~ ∞ ~~∅~~ | CB →- B  CC →- B |  |
| 8 |  | {∅} |  | {B} | C |  | A |  |  |  |  |  |  |  |  |  | AA →+ B  AB →+ B | BA ∞ A  BB ∞ A | CB →- B |  |
| 9 |  | {∅} |  | {B} | C |  | ∅ |  |  |  |  |  |  |  |  |  | AA →+ B | BA ∞ A  ~~B~~~~B~~ ∞ ~~∅~~ | CB →- B |  |
| 10 |  |  |  |  | ∅ |  | A |  |  |  |  |  |  |  |  |  | AB →+ B | BB ∞ A |  |  |
| 11 |  | {∅} |  | {∅} | C |  | A |  |  |  |  |  |  |  |  |  | AB →+ B | BB ∞ A | CB →- B |  |
| 12 |  | {C} |  | {B} | ∅ |  | A |  |  |  |  |  |  |  |  |  | AA →+ B  AB →+ B  AA →- C | BA ∞ A  BB ∞ A | CA ∞ ∅ |  |
| 13 |  | {C} |  | {B} | ∅ |  | ∅ |  |  |  |  |  |  |  |  |  | AA →+ B  AA →- C | BA ∞ A | CA ∞ ∅ |  |
| 14 |  | {C} |  | {B} | D |  | A |  | A |  | ∅ |  |  | {B} |  | {∅} | AA →- C  AA →+ B  AB →+ B  AC →- C | BA ∞ A  BB ∞ A  ~~B~~~~D~~ ∞ ~~∅~~ | CA ∞ ∅  CC ∞ ∅ | DB →- B  DD →- B |
| 15 |  | {C} |  | {B} | D |  | ∅ |  | A |  | ∅ |  |  | {B} |  | {∅} | AA →- C  AA →+ B  AC →- C | BA ∞ A  ~~B~~~~B~~ ∞ ~~∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | CA ∞ ∅  CC ∞ ∅ | DB →- B  DD →- B |
| 16 |  | {C} |  | {B} | D |  | A |  | A |  | D |  |  | {B} |  | {C} | AA →- C  AA →+ B  AB →+ B  AC →- C | BA ∞ A  BB ∞ A  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~A~~ ~~∞ ∅~~  CC ∞ D  CD ∞ D | DB →- B  DD →- B  DD →+ C  DC →+ C |
| 17 |  | {C} |  | {B} | D |  | ∅ |  | A |  | D |  |  | {B} |  | {C} | AA →- C  AA →+ B  AC →- C | BA ∞ A  BB ∞ ~~∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~A~~ ~~∞ ∅~~  CC ∞ D  CD ∞ D | DB →- B  DD →- B  DD →+ C  DC →+ C |
| 18 |  | {C} |  | {B} | D |  | ∅ |  | A |  | D |  |  | {B} |  | {∅} | AA →- C  AA →+ B  AC →- C | BA ∞ A  BB ∞ ~~∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~A~~ ~~∞ ∅~~  CC ∞ D | DB →- B  DD →- B  DC →+ C |
| 19 |  | {C} |  | {B} | D |  | ∅ |  | A |  | ∅ |  |  | {B} |  | {∅} | AA →- C  AA →+ B  AC →- C | BA ∞ A  BB ∞ ~~∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | CA ∞ ∅  CC ∞ ∅ | DB →- B  DD →- B |
| 20 |  | {∅} |  | {B} | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | AA →+ B  AB →+ B | BA ∞ A  BB ∞ A | CC ∞ A |  |
| 21 |  | {C} |  | {B} | D |  | A |  |  |  |  |  |  |  |  |  | AA →- C  AA →+ B  AB →+ B | BA ∞ A  BB ∞ A | CA ∞ ∅ | DB →- B |
| 22 |  | {C} |  | {B,D} | ∅ |  | A |  | A |  | ∅ |  | ∅ |  | A |  | AA →- C  AA →+ B  AA →+ D  AB →+ B  AC →- C  AD →+ D | BA ∞ A  BB ∞ A | CA ∞ ∅  CC ∞ ∅ | DA ∞ A  DD ∞ A |
| 23 |  | {C,B} |  | {D} | A |  | ∅ |  | A |  | ∅ |  | ∅ |  | A |  | AA →- C  AA →- B  AA →+ D  AB →- B  AC →- C  AD →+ D | BA ∞ ∅  BB ∞ ∅ | CA ∞ ∅  CC ∞ ∅ | DA ∞ A  DD ∞ A |
| 24 |  | {C,B} |  | {B,D} | A |  | A |  | A |  | ∅ |  | ∅ |  | A |  | AA →- C  AA →+ D  AC →- C  AD →+ D |  | CA ∞ ∅  CC ∞ ∅ | DA ∞ A  DD ∞ A |
| 25 |  | {B} |  | {B} | A |  | C |  | {∅} |  | {B} |  |  |  |  |  | AB →- B | BB ∞ C  BC ∞ C | CB →+ B  CC →+ B |  |

TODO: create some conflicting test cases. For example, A is associated with B, but the backRef of B is C.

OneToMany(Set) bi-directional (and ManyToOne)test on mix of persistent and transient instances

A transient instance cannot have an old value. Transient instance are italicized.

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| **#** | **A** | | | | **B** | | | | **C** | | | | **D** | | | | **A** | **B** | **C** | **D** |
| ***Old*** | | ***New*** | | ***Old*** | | ***New*** | | ***Old*** | | ***New*** | | ***Old*** | | ***New*** | |  |  |  |  |
| **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** |  |  |  |  |
| 25 |  | {∅} |  | {B} | ∅ |  | A |  |  |  |  |  |  |  |  |  | AA →+ B  AB →+ B | BA ∞ A  BB ∞ A |  |  |
| 26 |  | {∅} |  | {B} | ∅ |  | ∅ |  |  |  |  |  |  |  |  |  | AA →+ B | BA ∞ A |  |  |
| 27 |  | {∅} |  | {B, C} | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | AA →+ B  AA →+ C  AB →+ B  AC →+ C | BA ∞ A  BB ∞ A | CA ∞ A  CC ∞ A |  |
| 28 |  | {∅} |  | {B, C} | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | AA →+ B  AA →+ C  AB →+ B  AC →+ C | BA ∞ A  BB ∞ A | CA ∞ A  CC ∞ A |  |
| 29 |  | {C} |  | {B} | ∅ |  | A |  | A |  | ∅ |  |  |  |  |  | AA →- C  AA →+ B  AB →+ B  AC →- C | BA ∞ A  BB ∞ A | CA ∞ ∅  CC ∞ ∅ |  |
| 30 |  | {C} |  | {B} | ∅ |  | ∅ |  | A |  | ∅ |  |  |  |  |  | AA →- C  AA →+ B  AC →- C | BA ∞ A | CA ∞ ∅  CC ∞ ∅ |  |
| 31 |  | {∅} |  | {B} | C |  | A |  |  | {B} |  | {∅} |  |  |  |  | AA →+ B  AB →+ B | BA ∞ A  BB ∞ A  ~~B~~~~C~~ ∞ ~~∅~~ | CB →- B  CC →- B |  |
| 32 |  | {∅} |  | {B} | C |  | ∅ |  |  | {B} |  | {∅} |  |  |  |  | AA →+ B | BA ∞ A  BB ∞ ~~∅~~  ~~B~~~~C~~ ∞ ~~∅~~ | CB →- B  CC →- B |  |
| 33 |  | {∅} |  | {B} | C |  | A |  |  |  |  |  |  |  |  |  | AA →+ B  AB →+ B | BA ∞ A  BB ∞ A | CB →- B |  |
| 34 |  | {∅} |  | {B} | C |  | ∅ |  |  |  |  |  |  |  |  |  | AA →+ B | BA ∞ A  ~~B~~~~B~~ ∞ ~~∅~~ | CB →- B |  |
| 35 |  | {C} |  | {B} | ∅ |  | A |  |  |  |  |  |  |  |  |  | AA →+ B  AB →+ B  AA →- C | BA ∞ A  BB ∞ A | CA ∞ ∅ |  |
| 36 |  | {C} |  | {B} | ∅ |  | ∅ |  |  |  |  |  |  |  |  |  | AA →+ B  AA →- C | BA ∞ A | CA ∞ ∅ |  |
| 37 |  | {∅} |  | {B} | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | AA →+ B  AB →+ B  AC →+ C | BA ∞ A  BB ∞ A | AA →+ B  AB →+ B |  |

OneToMany (List) bi-directional (and ManyToOne) test on persistent instances

By default list has bag semantics if the index attribute is not specified. Investigate how duplicates are represented in JPA.

There is a consolidation step where if both actions are present from a bi-directional relationship, we use only one. If an index is used then that is used to control where the element is added. Conflicts are resolved by allowing duplicates. This behavior can be managed using a configuration parameter for each association (i.e., duplicates are not created on conflict).

The backRef actions are only valid if the element on the many side has a MapKey or a ListIndex.

The superscripts represent the following:

* **→+** Add a new element (**AddElementAction**)
* **→-** Remove an existing element (**RemoveElementAction**)
* **→Π** Re-position the element (**RepositionElementAction**)
* **~~→~~~~x~~**~~Incomplete operation due to incomplete information created by the backRef. The backRef does not know at this point if we need to do a RemoveElementAction or RepositionElementAction an existing item at that index. In the case of a Map, the backRef does not know for an existing key if the RemoveElementAction or a RepositionElementAction needs to be made. An action is supposed to be independently executed, if this distinction cannot be made then an IncompleteElementAction should be used and the type set within this action (add, remove or reposition).  
  An IncompleteElementAction should always be resolved otherwise it is an error. For e.g., test case 3 below shown an error condition.~~

If duplicates are allowed in the list, need to be careful about clearing the backRef. Because removing a duplicate element from the list should not clear the backRef. (See Test case 21).

NOTE: Duplicates are only allowed in collections that don’t have a MapKey or a ListIndex referenced in the element type. Because this setting constraints the entity to only one index or a map key. TODO: Test on different providers.

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| **#** | **A** | | | | **B** | | | | **C** | | | | **D** | | | | **A** | **B** | **C** | **D** |
| ***Old*** | | ***New*** | | ***Old*** | | ***New*** | | ***Old*** | | ***New*** | | ***Old*** | | ***New*** | |  |  |  |  |
| **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** |  |  |  |  |
| 1 |  | ∅ |  | 0.B | ∅ |  | A0 |  |  |  |  |  |  |  |  |  | A0.A →+ B  A0.B →+ B | BA ∞ A  BB ∞ A |  |  |
| 2 |  |  |  |  | ∅ |  | A0 |  |  |  |  |  |  |  |  |  | A0.B →+ B | BB ∞ A |  |  |
| 3 |  |  |  |  | ∅ |  | A0 |  |  |  |  |  |  |  |  |  | A0.B →+ B | BB ∞ A |  |  |
| 4 |  |  |  |  | ∅ |  | A0 |  | ∅ |  | A0 |  |  |  |  |  | A0.B →+ B  A0.C →+ C | BB ∞ A  CC ∞ A |  |  |
| 5 |  |  |  |  | ∅ |  | A |  |  |  |  |  |  |  |  |  | Ax.B →+ B | BB ∞ A |  |  |
| 6 |  | ∅ |  | 0.B | ∅ |  | ∅ |  |  |  |  |  |  |  |  |  | A0.A →+ B | BA ∞ A |  |  |
| 7 |  | ∅ |  | 0.B  1.C | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | A0.A →+ B  A1.A →+ C  Ax.B →+ B  Ax.C →+ C | BA ∞ A  BB ∞ A | CA ∞ A  CC ∞ A |  |
| 8 |  | 0.C  1.B |  | 0.B  1.C | A |  | A |  | A |  | A |  |  |  |  |  | A0.A →Π B  A1.A →Π C | BB= | CC= |  |
| 9 |  | 0.C  1.B |  | 0.B  1.C | A1 |  | A0 |  | A0 |  | A1 |  |  |  |  |  | A0.A →Π B  A1.A →Π C  A0.B → Π B  A1.C → Π C | BB= | CC= |  |
| 10 |  | 0.C |  | 0.B | ∅ |  | A |  | A |  | ∅ |  |  |  |  |  | A0.A →- C  A0.A →+ B  Ax.B →+ B  Ax.C →- C | BA ∞ A  BB ∞ A | CA ∞ ∅  CC ∞ ∅ |  |
| 11 |  | 0.C  1.B |  | 0.B | A |  | A |  | A |  | ∅ |  |  |  |  |  | A0.A →- C  A0.A →Π B  Ax.C →- C | BB= | CA ∞ ∅  CC ∞ ∅ |  |
| 12 |  | 0.C  1.B  2.D |  | 0.B  1.D | A |  | A |  | A |  | ∅ |  | A |  | A |  | A0.A →- C  A0.A →Π B  A1.A →Π D  Ax.C →- C | BB= | CA ∞ ∅  CC ∞ ∅ | DD= |
| 13 |  | 0.C  1.B  2.D |  | 0.D  1.B | A |  | A |  | A |  | ∅ |  | A |  | A |  | A0.A →- C  A0.A →Π D  Ax.C →- C | BB= | CA ∞ ∅  CC ∞ ∅ | DD= |
| 14 |  | 0.C  1.B  2.D |  | 0.D  1.B | A1 |  | A1 |  | A0 |  | ∅ |  | A2 |  | A0 |  | A0.A →- C  A0.A →Π D  A0.C →- C  A0.D →Π D | BB= | CA ∞ ∅  CC ∞ ∅ | DD= |
| 14 |  | 0.C  1.B |  | 0.D  1.C | A1 |  | ∅ |  | A0 |  | A1 |  | ∅ |  | A0 |  | A0.A →- B  A1.A →Π C  A0.A →+ D  A0.D →+ D  A1.C →Π C  A0.B →- B | BA ∞ ∅  BB ∞ ∅ | CC= | DA ∞ A  DD ∞ A |
| 15 |  | 0.C |  | 0.B | ∅ |  | ∅ |  | A |  | ∅ |  |  |  |  |  | A0.A →- C  A0.A →+ B  A0.C →- C | BA ∞ A | CA ∞ ∅  CC ∞ ∅ |  |
| 16 |  | ∅ |  | 0.B | C |  | A |  |  | 0.B |  | ∅ |  |  |  |  | A0.A →+ B  Ax.B →+ B | BA ∞ A  BB ∞ A  ~~B~~~~C~~ ∞ ~~∅~~ | Cx.B →- B  C0.C →- B |  |
| 17 |  | ∅ |  | 0.B | C |  | ∅ |  |  | 0.B |  | ∅ |  |  |  |  | A0.A →+ B | BA ∞ A  ~~B~~~~B~~ ~~∞ ∅~~  ~~B~~~~C~~ ∞ ~~∅~~ | Cx.B →- B  C0.C →- B |  |
| 18 |  | ∅ |  | 0.B | C |  | A |  |  |  |  |  |  |  |  |  | A0.A →+ B  Ax.B →+ B | BA ∞ A  BB ∞ A | Cx.B →- B |  |
| 19 |  | ∅ |  | 0.B | C |  | ∅ |  |  |  |  |  |  |  |  |  | A0.A →+ B | BA ∞ A  ~~B~~~~B~~ ∞ ~~∅~~ | Cx.B →- B |  |
| 20 |  | 0.C |  | 0.B | ∅ |  | A |  |  |  |  |  |  |  |  |  | A0.A →- C  A0.A →+ B  Ax.B →+ B | BA ∞ A  BB ∞ A | CA ∞ ∅ |  |
| 21 |  | 0.C  1.C |  | 0.B  1.C | ∅ |  | A |  |  |  |  |  |  |  |  |  | A0.A →- C  A0.A →+ B  Ax.B →+ B | BA ∞ A  BB ∞ A | CA= |  |
| 22 |  | 0.C |  | 0.B | ∅ |  | ∅ |  |  |  |  |  |  |  |  |  | A0.A →- C  A0.A →+ B | BA ∞ A  ~~B~~~~B~~ ~~∞ ∅~~ | CA ∞ ∅ |  |
| 23 |  | 0.C |  | 0.B | D |  | A |  | A |  | ∅ |  |  | 0.B |  | ∅ | A0.A →- C  A0.A →+ B  Ax.B →+ B  Ax.C →- C | BA ∞ A  BB ∞ A  ~~B~~~~D~~ ∞ ~~∅~~ | CA ∞ ∅  CC ∞ ∅ | Dx.B →- B  D0.D →- B |
| 24 |  | 0.C |  | 0.B | D |  | ∅ |  | A |  | ∅ |  |  | 0.B |  | ∅ | A0.A →- C  A0.A →+ B  Ax.C →- C | BA ∞ A  ~~B~~~~B~~ ~~∞ ∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | CA ∞ ∅  CC ∞ ∅ | Dx.B →- B  D0.D →- B |
| 25 |  | 0.C |  | 0.B | D |  | A |  | A |  | D |  |  | 0.B |  | 0.C | A0.A →- C  A0.A →+ B  Ax.B →+ B  Ax.C →- C | BA ∞ A  BB ∞ A  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~A~~ ~~∞ ∅~~  CC ∞ D  CD ∞ D | Dx.B →- B  D0.D →- B  D0.D →+ C  Dx.C →+ C |
| 26 |  | 0.C |  | 0.B | D |  | ∅ |  | A |  | D |  |  | 0.B |  | 0.C | A0.A →- C  A0.A →+ B  Ax.C →- C | BA ∞ A  ~~B~~~~B~~ ~~∞ ∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~A~~ ~~∞ ∅~~  CC ∞ D  CD ∞ D | Dx.B →- B  D0.D →- B  D0.D →+ C  Dx.C →+ C |
| 27 |  | 0.C |  | 0.B | D |  | ∅ |  | A |  | D |  |  | 0.B |  | ∅ | A0.A →- C  A0.A →+ B  Ax.C →- C | BA ∞ A  ~~B~~~~B~~ ~~∞ ∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~A~~ ~~∞ ∅~~  CC ∞ D | Dx.B →- B  D0.D →- B  Dx.C →+ C |
| 29 |  | ∅ |  | 0.B | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | A0.A →+ B  Ax.B →+ B  Ax.C →+ C | BA ∞ A  BB ∞ A | CC ∞ A |  |
| 30 |  | 0.C |  | 0.C |  |  |  |  | A |  | ∅ |  |  |  |  |  | Ax.C →- C |  | CC ∞ ∅ |  |
| 31 |  | 0.D |  | 0.B | C |  | A |  |  |  |  |  |  |  |  |  | A0.A →- D  A0.A →+ B  Ax.B →+ B | BA ∞ A  BB ∞ A | Cx.B →- B | DA ∞ ∅ |

OneToMany (Map) bi-directional (and ManyToOne) test on persistent instances

We are going to model **dynamic properties** for map keys and treat them as attributes of the collection owner. So the IncompleteElementAction is not necessary for the map collection that has a MapKey defined.

If a MapKey is not present, we will not process the backRef and will only allow updates from the Owner collection.

The +, - actions are for informational purposes and used to resolve conflicts. The -<key> action is used to remove a key from the map.

**Algorithm**

1. Removed keys - the backRef will be set to null if there are no more references to the value object
2. Added keys – the dynamic property (key) will be set to the appropriate value and the backRef set appropriately.

If the relationship is OneToMany, the backRef needs to be set to the new owner and all references from the old owner needs to be cleared (or those keys removed).

If the relationship is ManyToMany, the backRef adds the new Owner

1. Changed keys - the old object will have all keys to this object removed

For all the above actions, before the map is processed a tally of the references to each value is computed. This allows to decide if a backRef needs to be cleared.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **#** | **A** | | | | **B** | | | | **C** | | | | **D** | | | | **A** | **B** | **C** | **D** |
| ***Old*** | | ***New*** | | ***Old*** | | ***New*** | | ***Old*** | | ***New*** | | ***Old*** | | ***New*** | |  |  |  |  |
| **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** | **∞** | **→** |  |  |  |  |
| 1 |  | ∅ |  | K1:B | ∅ |  | AK1 |  |  |  |  |  |  |  |  |  | AK1.A → B  AB →+ B | BK1.A ∞ A  BK1.B ∞ A |  |  |
| 2 |  | ∅ |  | K1:B | ∅ |  | A |  |  |  |  |  |  |  |  |  | AK1.A → B  AB →+ B | BK1.A ∞ A  BB ∞ A |  |  |
| 3 |  | ∅ |  | K1:B | ∅ |  | ∅ |  |  |  |  |  |  |  |  |  | AK1.A → B | BK1.A ∞ A |  |  |
| 4 |  | ∅ |  | K1:B  K2:C | ∅ |  | AK1 |  | ∅ |  | AK2 |  |  |  |  |  | AK1.A → B  AK2.A → C  AB →+ B  AC →+ C | BK1.A ∞ A  BK1.B ∞ A | CK2.A ∞ A  CK2.C ∞ A |  |
| 5 |  | ∅ |  | K1:B  K2:C | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | AK1.A → B  AK2.A → C  AB →+ B  AC →+ C | BK1.A ∞ A  BB ∞ A | CK2.A ∞ A  CC ∞ A |  |
| 6 |  | ∅ |  | K1:B  K2:C | A |  | ∅ |  | ∅ |  | A |  |  |  |  |  | AK1.A → B  AB →- B  AC →+ C  AK2.A → C | BK1.A ∞ A  ~~B~~~~B~~ ~~∞ ∅~~ | CK1.A ∞ A  CC ∞ A |  |
| 7 |  | K1:C  K2:B |  | K1:B  K2:C | A |  | A |  | A |  | A |  |  |  |  |  | AK1.A → B  AK2.A → C | BK1.A ∞ A  ~~B~~~~K2.A~~ ~~∞ ∅~~ | CK2.A ∞ A  ~~C~~~~K1.A~~ ~~∞ ∅~~ |  |
| 8 |  | K1:C  K2:B |  | K1:B  K2:C | AK2 |  | AK1 |  | AK1 |  | AK2 |  |  |  |  |  | AK1.A → B  AK2.A → C  AK1.B → B  AK2.C → C | BK1.A ∞ A  ~~B~~~~K2.A~~ ~~∞ ∅~~  BK1.B ∞ A | CK2.A ∞ A  ~~C~~~~K1.A~~ ~~∞ ∅~~  CK2.C ∞ A |  |
| 9 |  | K1:C |  | K1:B  K2:D | ∅ |  | AK1 |  | AK1 |  | ∅ |  | ∅ |  | AK2 |  | AK1.A → B  AK2.A → D  AB →+ B  AD →+ D  AC →- C | BK1.B ∞ A  BK1.B ∞ A | CK1.A ∞ ∅  CC ∞ ∅ | DK2.D ∞ A  DK2.A ∞ A |
| 10 |  | K1:C |  | K1:B | ∅ |  | A |  | A |  | ∅ |  |  |  |  |  | AK1.A → B  AC →- C  AB →+ B | BK1.A ∞ A  BB ∞ A | CK1.A ∞ ∅  CC ∞ ∅ |  |
| 11 |  | K1:C |  | K1:B | ∅ |  | ∅ |  | A |  | ∅ |  |  |  |  |  | AK1.A → B  AC →- C | BA ∞ A | CK1.A ∞ ∅  CC ∞ ∅ |  |
| 12 |  | K1:C |  | K1:B  K2:D | ∅ |  | AK1 |  | AK1 |  | AK1 |  | ∅ |  | AK2 |  | AK1.A → B  AK2.A → D  AB →+ B  AD →+ D | BK1.B ∞ A  BK1.A ∞ A | CK1.A ∞ ∅ | DK2.D ∞ A  DK2.A ∞ A |
| 13 |  | K1:C |  | K1:B  K2:D | ∅ |  | AK1 |  | AK1 |  | AK2 |  | ∅ |  | AK2 |  | AK1.A → B  AK2.A → D  AB →+ B  AD →+ D | BK1.B ∞ A  BK1.A ∞ A | CK1.A ∞ ∅ | DK2.D ∞ A  DK2.A ∞ A |
| 14 |  | K1:C |  | K1:B  K2:D | ∅ |  | A |  | A |  | A |  | ∅ |  | A |  | AK1.A → B  AK2.A → D  AB →+ B  AD →+ D | BB ∞ A  BK1.A ∞ A | CK1.A ∞ ∅ | DD ∞ A  DK2.A ∞ A |
| 15 |  | ∅ |  | K1:B | C |  | A |  |  | K1:B |  | ∅ |  |  |  |  | AK1.A → B  AB →+ B | BK1.A ∞ A  BB ∞ A  ~~B~~~~C~~ ∞ ~~∅~~ | C-K1  CB →- B |  |
| 16 |  | ∅ |  | K1:B | C |  | ∅ |  |  | K1:B |  | ∅ |  |  |  |  | AK1.A → B | BK1.A ∞ A  BB ∞ ~~∅~~  ~~B~~~~B~~ ∞ ~~∅~~ | C-K1­­­  CB →- B |  |
| 17 |  | ∅ |  | K1:B | C |  | A |  |  |  |  |  |  |  |  |  | AK1.A → B  AB →+ B | BK1.A ∞ A  BB ∞ A | CB →- B |  |
| 18 |  | ∅ |  | K1:B | C |  | ∅ |  |  |  |  |  |  |  |  |  | AK1.A → B | BK1.A ∞ A  ~~B~~~~B~~ ∞ ~~∅~~ | CB →- B |  |
| 19 |  | K1:C |  | K1:B | ∅ |  | A |  |  |  |  |  |  |  |  |  | AK1.A → B  AB →+ B | BK1.A ∞ A  BB ∞ A | CK1.A ∞ ∅ |  |
| 20 |  | K1:C |  | K1:B | ∅ |  | ∅ |  |  |  |  |  |  |  |  |  | AK1.A → B | BK1.A ∞ A | CK1.A ∞ ∅ |  |
| 21 |  | K1:C |  | K1:B | D |  | A |  | A |  | ∅ |  |  | K1:B |  | ∅ | AK1.A → B  AC →- C  AB →+ B | BK1.A ∞ A  BB ∞ A  ~~B~~~~K1.D~~ ∞ ~~∅~~ | CK1.A ∞ ∅  CC ∞ ∅ | D-K1  DB →- B |
| 22 |  | K1:C |  | K1:B | D |  | ∅ |  | A |  | ∅ |  |  | K1:B |  | ∅ | AK1.A → B  AC →- C | BK1.A ∞ A  ~~B~~~~B~~ ∞ ~~∅~~  ~~B~~~~K1.D~~ ∞ ~~∅~~ | CK1.A ∞ ∅  CC ∞ ∅ | D-K1  DB →- B |
| 23 |  | K1:C |  | K1:B | D |  | A |  | A |  | D |  |  | K1:B |  | K1:C | AK1.A → B  AC →- C  AB →+ B | BK1.A ∞ A  BB ∞ A  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~K1.A~~ ~~∞ ∅~~  CC ∞ D  CK1.D ∞ D | DK1.D → C  DB →- B  DC →+ C |
| 24 |  | K1:C |  | K1:B | D |  | ∅ |  | A |  | D |  |  | K1:B |  | K1:C | AK1.A → B  AC →- C | BK1.A ∞ A  BB ∞ ~~∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~K1.A~~ ~~∞ ∅~~  CC ∞ D  CK1.D ∞ D | DK1.D → C  DB →- B  DC →+ C |
| 25 |  | K1:C |  | K1:B | D |  | ∅ |  | A |  | D |  |  | K1:B |  | ∅ | AK1.A → B  AC →- C | BK1.A ∞ A  BB ∞ ~~∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | ~~C~~~~K1.A~~ ~~∞ ∅~~  CC ∞ D | D-K1  DB →- B  DC →+ C |
| 26 |  | K1:C |  | K1:B | D |  | ∅ |  | A |  | ∅ |  |  | K1:B |  | ∅ | AK1.A → B  AC →- C | BK1.A ∞ A  BB ∞ ~~∅~~  ~~B~~~~D~~ ∞ ~~∅~~ | CK1.A ∞ ∅  CC ∞ ∅ | D-K1  DB →- B |
| 27 |  | ∅ |  | K1:B | ∅ |  | A |  | ∅ |  | A |  |  |  |  |  | AK1.A → B  AB →+ B  AC →+ C | BK1.A ∞ A  BB ∞ A | CC ∞ A |  |
| 28 |  | K1:D |  | K1:B | C |  | A |  |  |  |  |  |  |  |  |  | AK1.A → B  Ax.B →x B | BK1.A ∞ A  BB ∞ A | CB →- B | DK1.A ∞ ∅ |

Notes

The first four columns specify what is present in the input. The last four columns specify the desired output in the database. An empty column represents that that data is not present in the input.

Additional tests to consider

* Introduce an annotation or configuration to resolve the IncompleteElementAction behavior in the absence of the collection owner action
* Test collection of data types (e.g., String, Embeddable etc…)