How to Use CohortAlgebra R Package

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1 Introduction

(This package is NOT part of HADES.)

The idea behind this package is to allow the construction of new cohorts from previously instantiated cohorts in the cohort table. All cohorts in OHDSI have a standard definition: "A cohort is a set of persons who satisfy one or more inclusion criteria for a duration of time."

- One person may belong to multiple cohorts
- One person may belong to the same cohort for multiple different time periods
- One person may not belong to the same cohort multiple times during the same period of time
- A cohort may have zero or more members

This is represented in a cohort table as cohort_definition_id, subject_id, cohort_start_date and cohort_end_date. For more details about the concept of a cohort please review The Book of OHDSI.

This package allows the creation of new cohorts from previously instantiated cohort table using cohort algebra (similar to temporal set algebra). The output is one or more new cohorts.

1.1 Installation

- This is an installable R-package that may be installed as follows:

```
remotes::install_github("OHDSI/CohortAlgebra")
```

```
#> Consider adding 'DATABASECONNECTOR_JAR_FOLDER='D:/windows_temp/AppData/Local/Temp/rtemp\RtmpWsEwR0\j
#> DatabaseConnector postgresql JDBC driver downloaded to 'D:/windows_temp/AppData/Local/Temp/rtemp\Rtm
```

1.2 Cohort UNION

- Given two or more cohorts, an UNION operator on these cohorts creates a new cohort with continuous days the persons was present in any of the cohorts. For example: given a cohort table as follows

```
cohort
```

```
#> # A tibble: 3 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 2022-01-01      2022-03-01
#> 2                  2         1 2022-02-10      2022-05-10
#> 3                  2         1 2022-08-15      2022-12-30
```

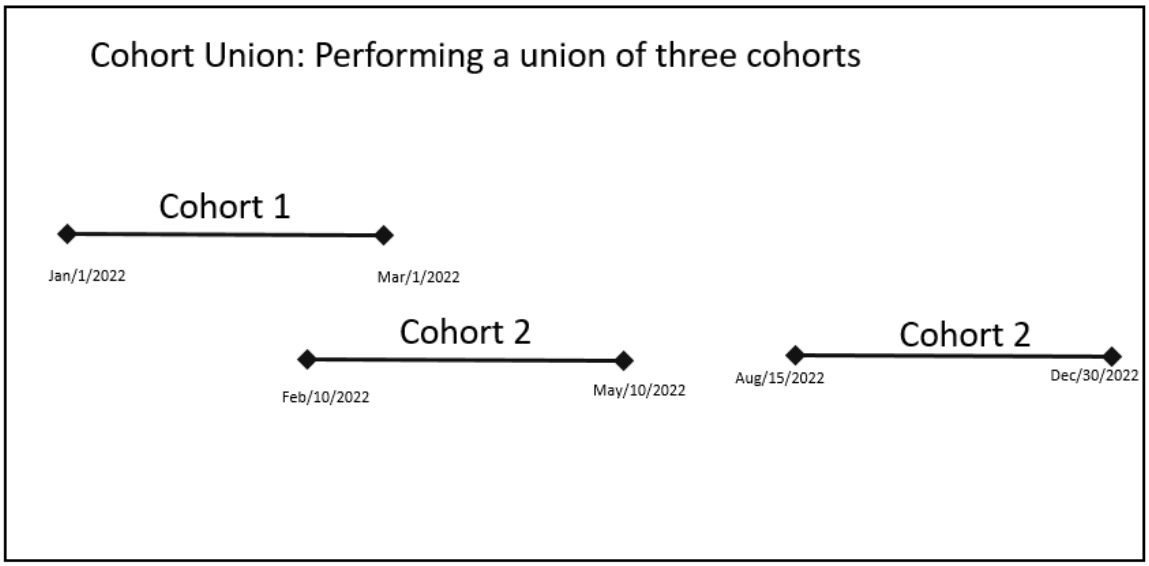
```
#> Connecting using PostgreSQL driver
```

The union of the two cohorts is expected to give us

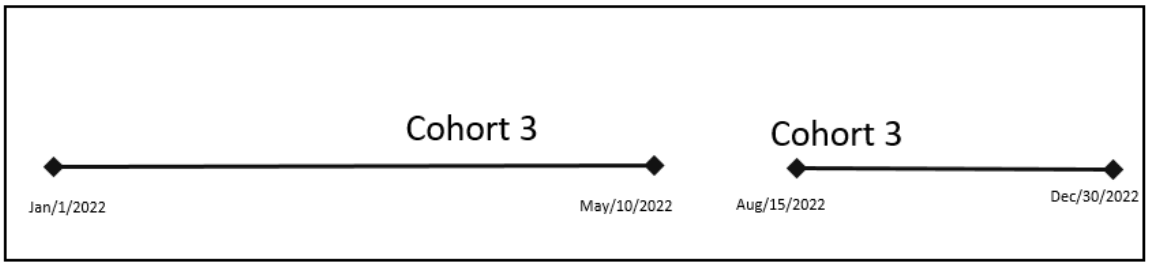
```
cohortExpected
```

```
#> # A tibble: 2 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  3         1 2022-01-01      2022-05-10
#> 2                  3         1 2022-08-15      2022-12-30
```

Input



Output



To perform Cohort Union, we use the unionCohorts function. This function requires as an input a data.frame called oldToNewCohortId. Here we specify the cohort id's of the cohorts we want to union. The newCohortId is the cohortId of the resultant cohort. The oldCohortId are cohorts that are already in the cohort table.

```
oldToNewCohortId <-
  dplyr::tibble(
    oldCohortId = c(1, 2, 2),
    newCohortId = c(3, 3, 3)
  )

CohortAlgebra::unionCohorts(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  oldToNewCohortId = oldToNewCohortId
)
```

```
#> Currently in a tryCatch or withCallingHandlers block, so unable to add global calling handlers. Paral

#>  Creating cohort eras.
#>   |
```

```
#> Executing SQL took 2.04 secs
```

```
#>  Saving cohort eras.
#>   |
```

Now we will have a new cohortId '3' which is the union of cohortId's 1 and 2.

```
data
```

```
#> # A tibble: 2 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  3         1 2022-01-01      2022-05-10
#> 2                  3         1 2022-08-15      2022-12-30
```

Note: if the target cohort table had a cohort with cohortId = 3, before running the union function - this would cause a conflict. In those cases, the union function would not run. We can purge all records for cohortId = 3 from the target cohort table. The parameter purgeConflicts will delete any cohort records in the cohort table where cohortId is the cohortId of the newCohort.

1.3 InterSect Cohort

- Given two or more cohorts, an INTERSECT operator on these cohorts creates a new cohort with continuous days the persons was present in ALL of the cohorts.

1.3.1 Intersect cohort example 1

Input:

```
cohort
```

```
#> # A tibble: 2 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 2022-01-01      2022-01-15
#> 2                  2         1 2021-12-15      2022-01-30
```

```
CohortAlgebra::intersectCohorts(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  cohortIds = c(1, 2),
  newCohortId = 3
)
```

```
#>  Intersecting cohorts.
#>   |
```

```
#> Executing SQL took 1.62 secs
```

```
#>  Creating cohort eras.
#>   |
#>  Saving cohort eras.
#>   |
#>  Saving cohort intersects
#>   |
```

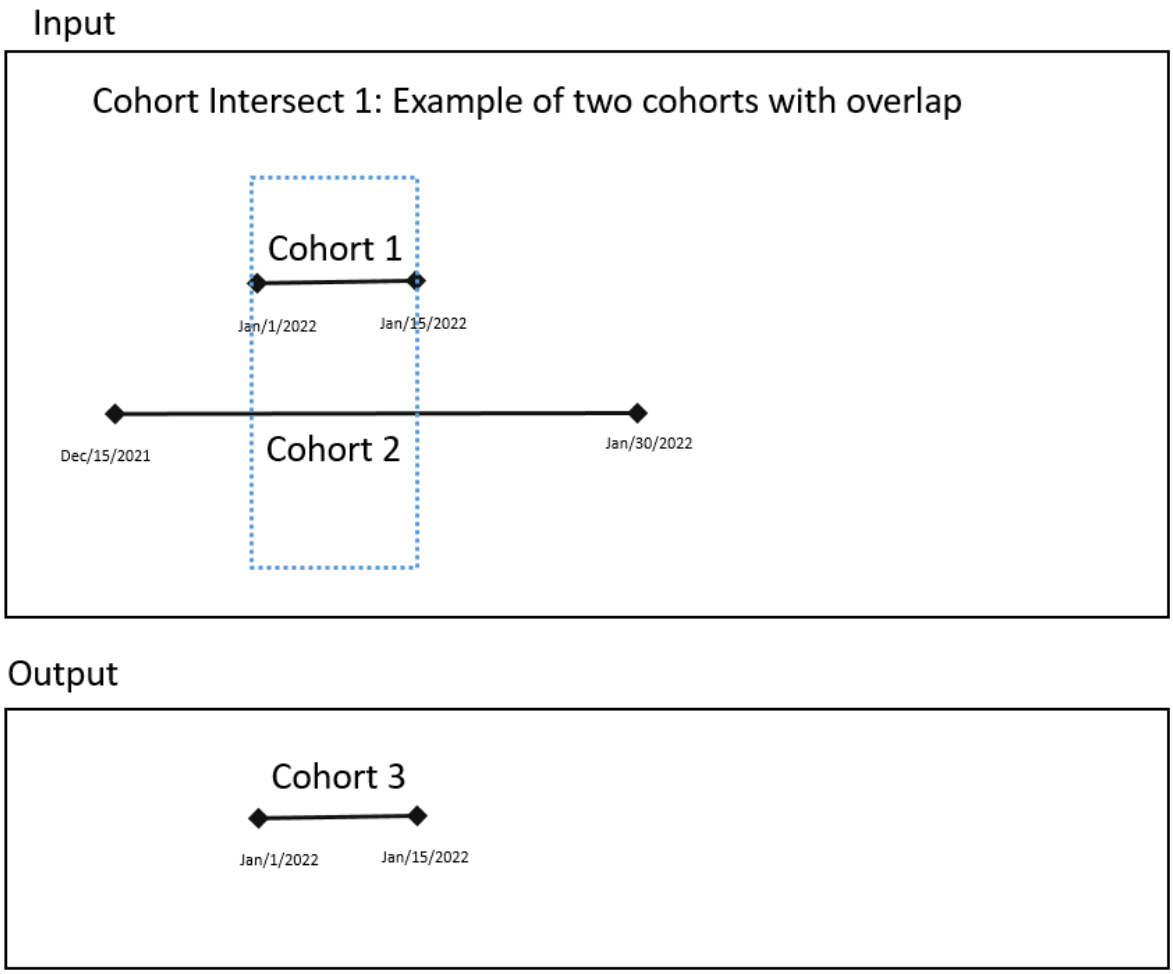


Figure 1: Cohort Intersect 1

Output

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  3         1 2022-01-01      2022-01-15
```

1.3.2 Intersect cohort example 2

Input:

```
cohort
```

```
#> # A tibble: 3 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 2022-01-01      2022-01-15
#> 2                  2         1 2021-12-15      2022-01-05
#> 3                  2         1 2022-01-10      2022-01-30
```

```
CohortAlgebra::intersectCohorts(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  cohortIds = c(1, 2),
  newCohortId = 3
)
```

```
#>  Intersecting cohorts.
#>   |
```

```
#> Executing SQL took 0.159 secs
```

```
#>  Creating cohort eras.
#>   |
#>  Saving cohort eras.
#>   |
#>  Saving cohort intersects
#>   |
```

Output

```
#> # A tibble: 2 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  3         1 2022-01-01      2022-01-05
#> 2                  3         1 2022-01-10      2022-01-15
```

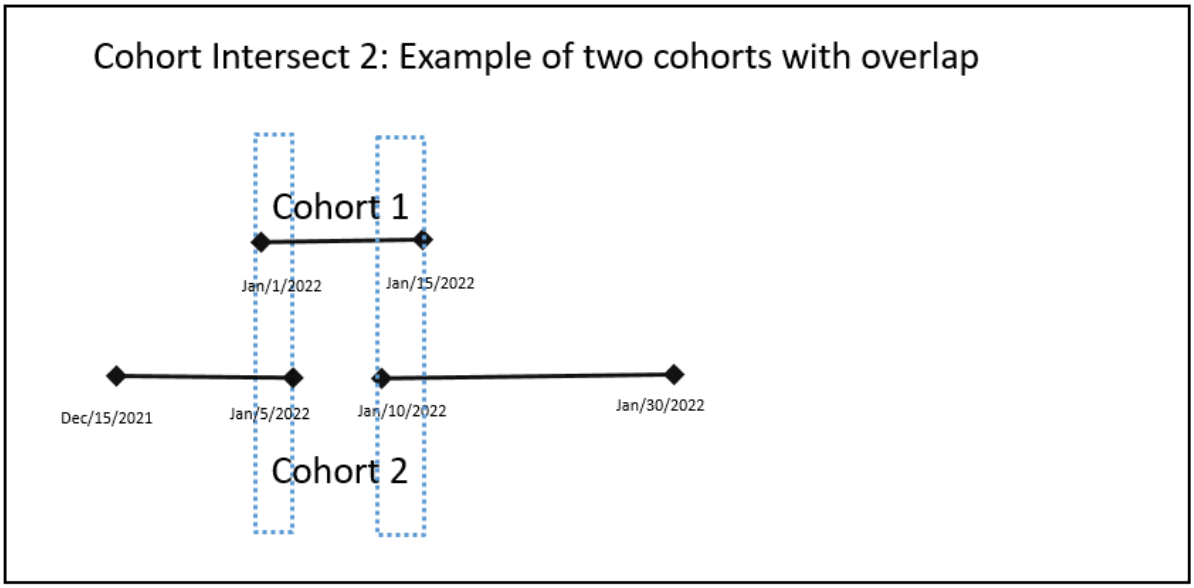
1.3.3 Intersect cohort example 3

Input:

```
cohort
```

```
#> # A tibble: 3 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 2022-01-01      2022-01-15
#> 2                  2         1 2021-12-15      2022-01-30
#> 3                  3         1 2022-03-01      2022-03-15
```

Input



Output

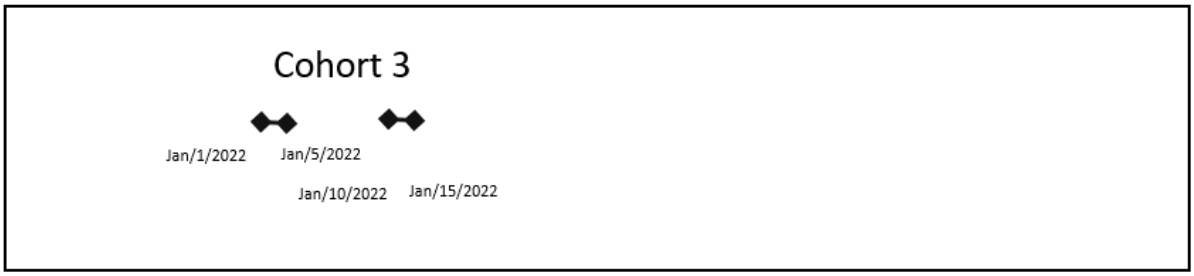


Figure 2: Cohort Intersect 2

```
CohortAlgebra::intersectCohorts(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  cohortIds = c(1, 2, 3),
  newCohortId = 4
)
```

```
#>  Intersecting cohorts.
#>   |
```

```
#> Executing SQL took 1.44 secs
```

```
#>  Creating cohort eras.
#>   |
#>  Saving cohort eras.
#>   |
#>  Saving cohort intersects
#>   |
```

Output

```
data
```

```
#> # A tibble: 0 x 4
#> # ... with 4 variables: cohortDefinitionId <dbl>, subjectId <dbl>, cohortStartDate <date>, cohortEndD
```

1.3.4 Intersect cohort example 4

Input:

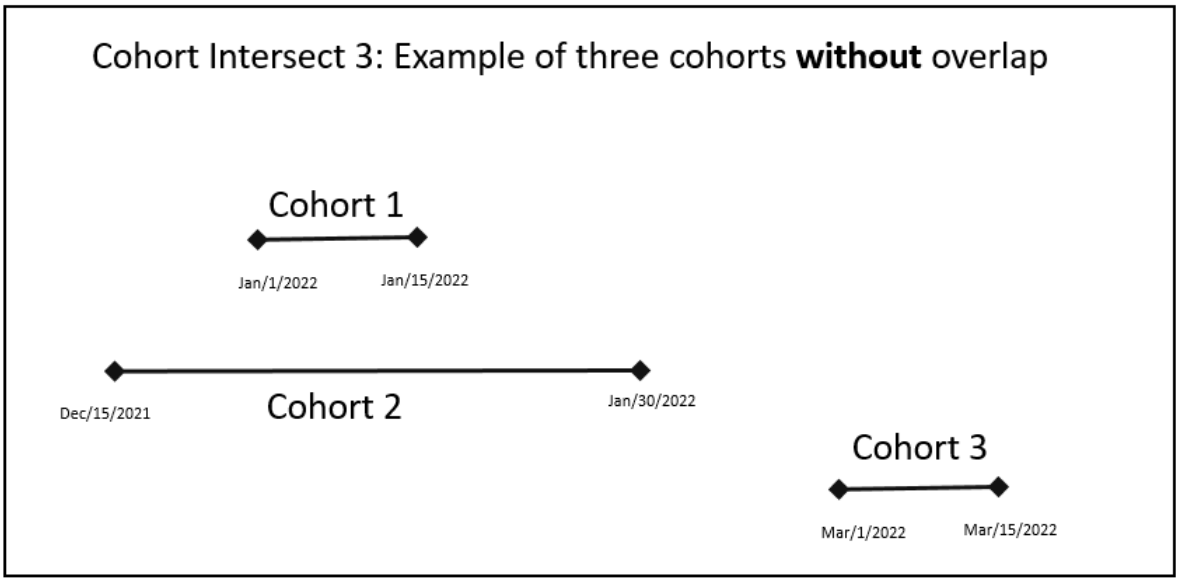
```
cohort
```

```
#> # A tibble: 2 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 2022-01-01      2022-01-15
#> 2                  2         1 2021-12-15      2022-01-30
```

```
CohortAlgebra::intersectCohorts(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  cohortIds = c(1, 2, 3),
  newCohortId = 4
)
```

```
#>  Intersecting cohorts.
#>   |
```

Input



Output

NULL Cohort – i.e. no cohort is created

Figure 3: Cohort Intersect 3

```
#> Executing SQL took 0.138 secs

#>  Creating cohort eras.
#>   |
#>  Saving cohort eras.
#>   |
#>  Saving cohort intersects
#>   |
```

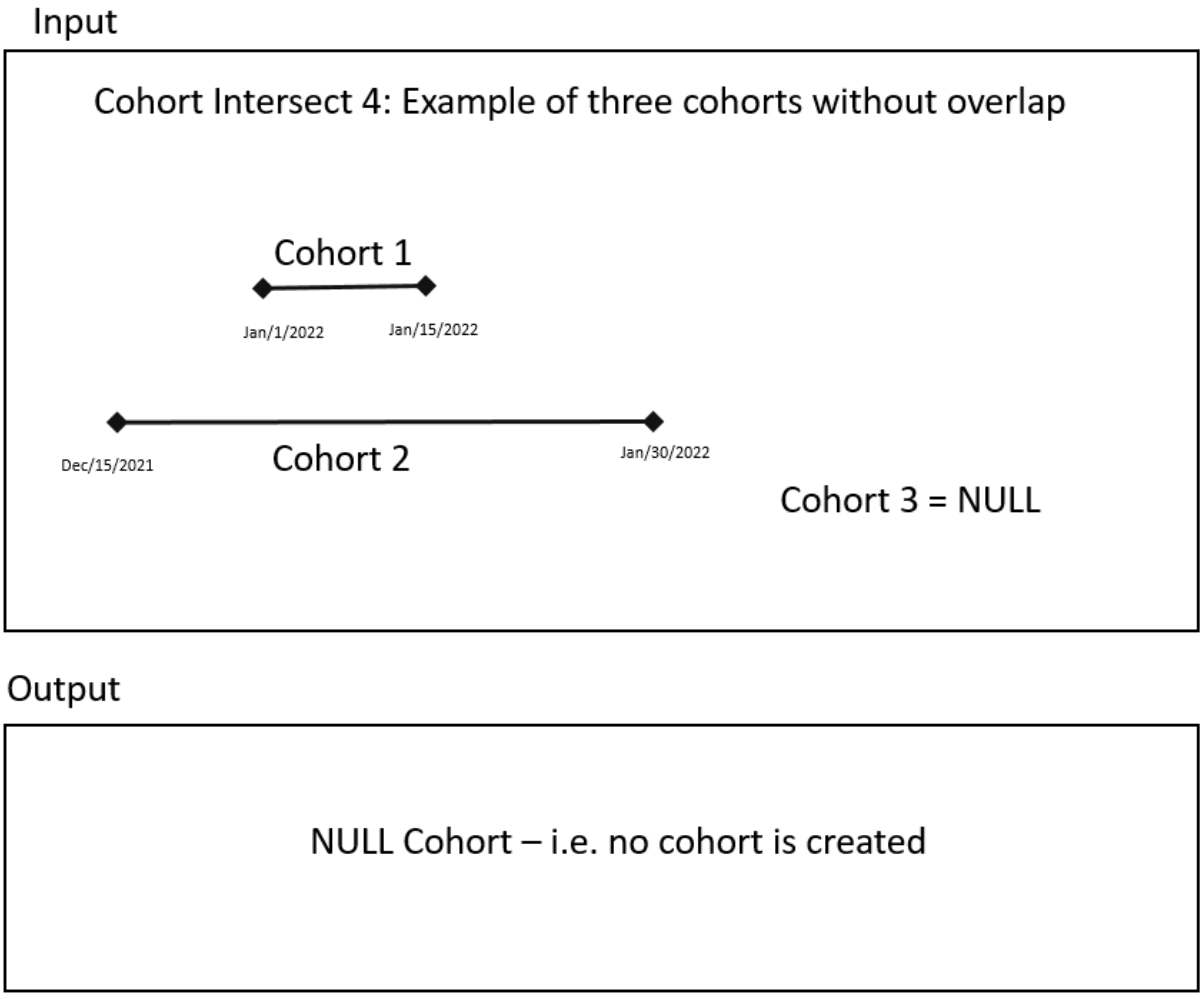


Figure 4: Cohort Intersect 4

Output

```
data
```

```
#> # A tibble: 0 x 4
#> # ... with 4 variables: cohortDefinitionId <dbl>, subjectId <dbl>, cohortStartDate <date>, cohortEndD
```

1.3.5 Intersect cohort example 5

Input:

```
cohort
```

```
#> # A tibble: 2 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 2022-01-01      2022-01-01
#> 2                  2         1 2022-01-01      2022-01-02
```

```
CohortAlgebra::intersectCohorts(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  cohortIds = c(1, 2),
  newCohortId = 3
)
```

```
#>  Intersecting cohorts.
#>   |

#> Executing SQL took 0.445 secs

#>  Creating cohort eras.
#>   |
#>  Saving cohort eras.
#>   |
#>  Saving cohort intersects
#>   |
```

Output

```
data
```

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  3         1 2022-01-01      2022-01-01
```

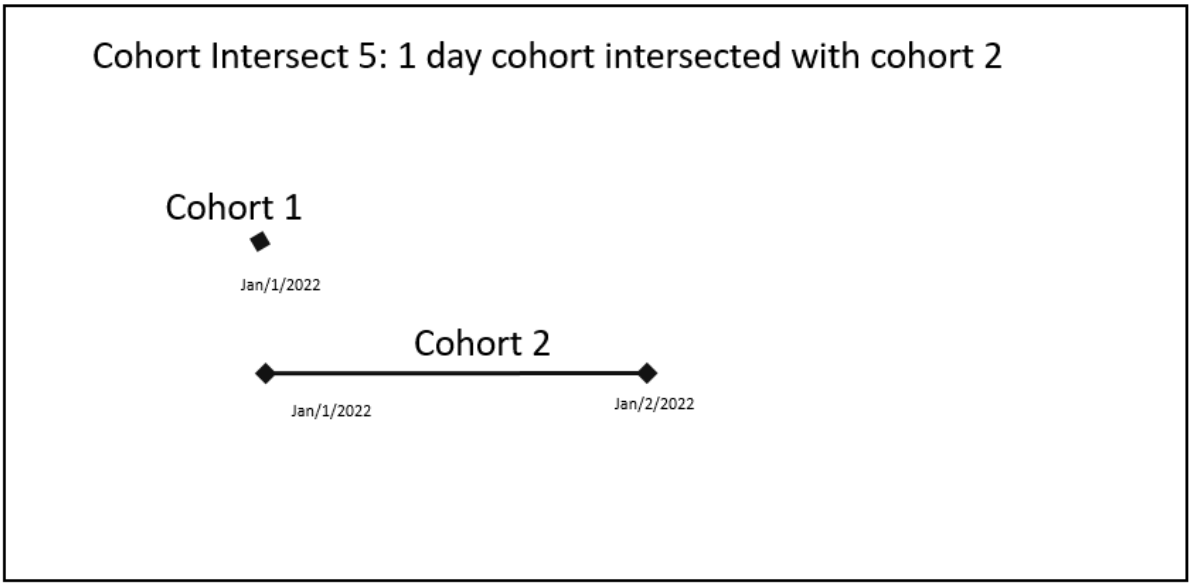
1.4 Minus Cohort

Input:

```
cohort
```

```
#> # A tibble: 2 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 2022-01-01      2022-03-01
#> 2                  2         1 2022-02-10      2022-05-10
```

Input



Output

Figure 5: Cohort Intersect 5

```
CohortAlgebra::minusCohorts(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  firstCohortId = 1,
  secondCohortId = 2,
  newCohortId = 3
)
```

```
#> Performing minus operation.
#>  Intersecting cohorts.
#>   |

#> Executing SQL took 0.582 secs

#>  Creating cohort eras.
#>   |
#>  Saving cohort eras.
#>   |
#>  Saving cohort intersects
#>   |
#>   |

#> Executing SQL took 0.324 secs

#> Saving output.
#>   |

#> Executing SQL took 0.0248 secs
```

Output for example 1

```
data
```

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  3         1 2022-01-01      2022-02-09
```

But if the cohorts are switched, i.e. minus cohort 1 from Cohort 2

```
CohortAlgebra::minusCohorts(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  firstCohortId = 2,
  secondCohortId = 1,
  newCohortId = 4
)
```

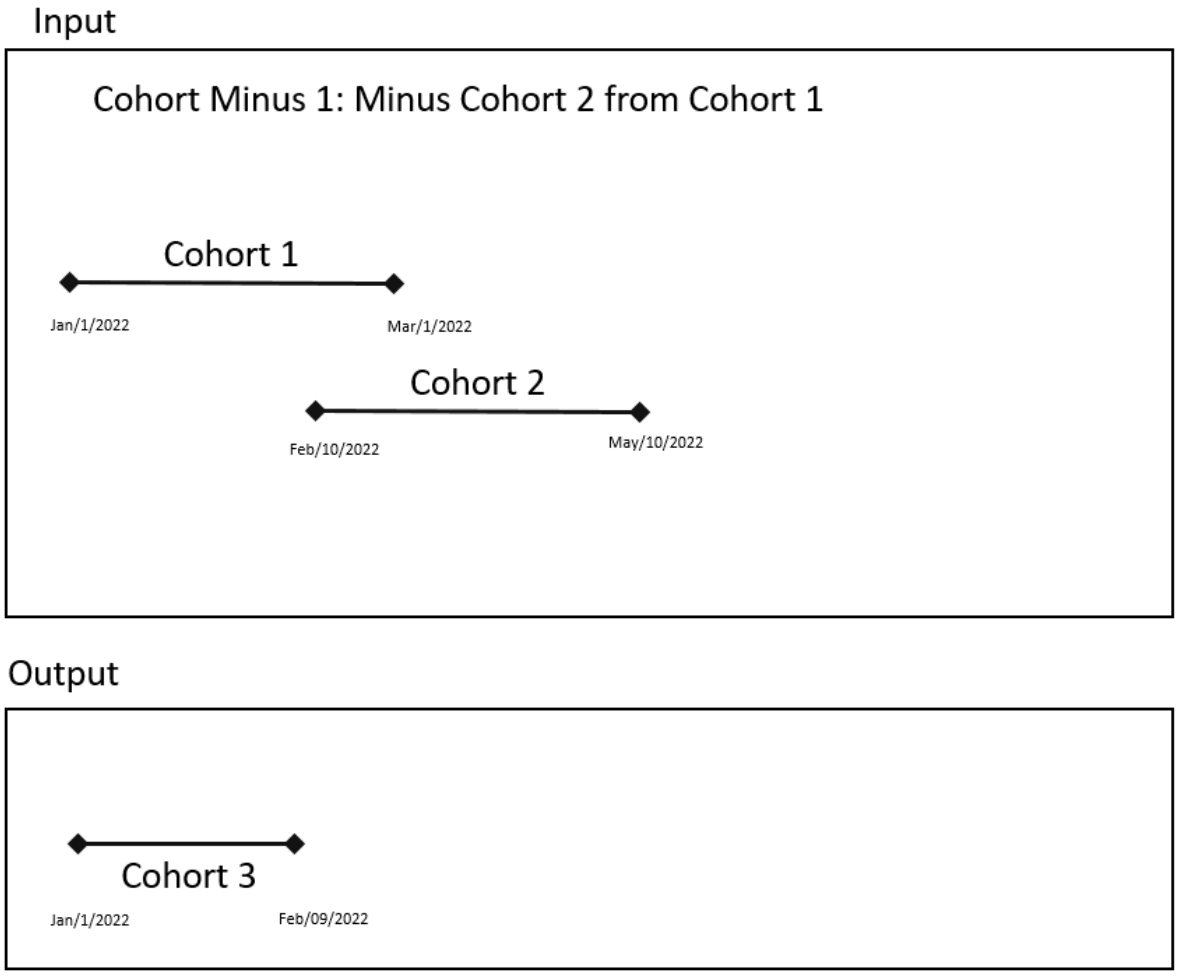


Figure 6: Cohort Minus

```
#> Performing minus operation.
#>  Intersecting cohorts.
#>   |

#> Executing SQL took 0.135 secs

#>  Creating cohort eras.
#>   |
#>  Saving cohort eras.
#>   |
#>  Saving cohort intersects
#>   |
#>   |

#> Executing SQL took 0.0277 secs

#> Saving output.
#>   |

#> Executing SQL took 0.041 secs
```

Output

```
data
```

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  4         1 2022-03-02      2022-05-10
```

Sequence of cohorts are important for minusCohort

1.5 Modify Cohort

Sometimes there is a need to modify a previously instantiated cohorts. Modification may be censoring (left or right) based on calendar date. This may be done using modifyCohort as follows:

```
#> Connecting using PostgreSQL driver
```

1.5.1 Example 1: Modify cohort based on calendar date censoring.

Let us say we have a simple cohort as follows:

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 1999-01-01      1999-01-31
```

We can censor the dates (left, right, or both). Parameter `cohortStartCensorDate` performs left censor, while `cohortEndEndCensorDate` performs right censor. This function is useful if you need to force exit based on calendar dates.

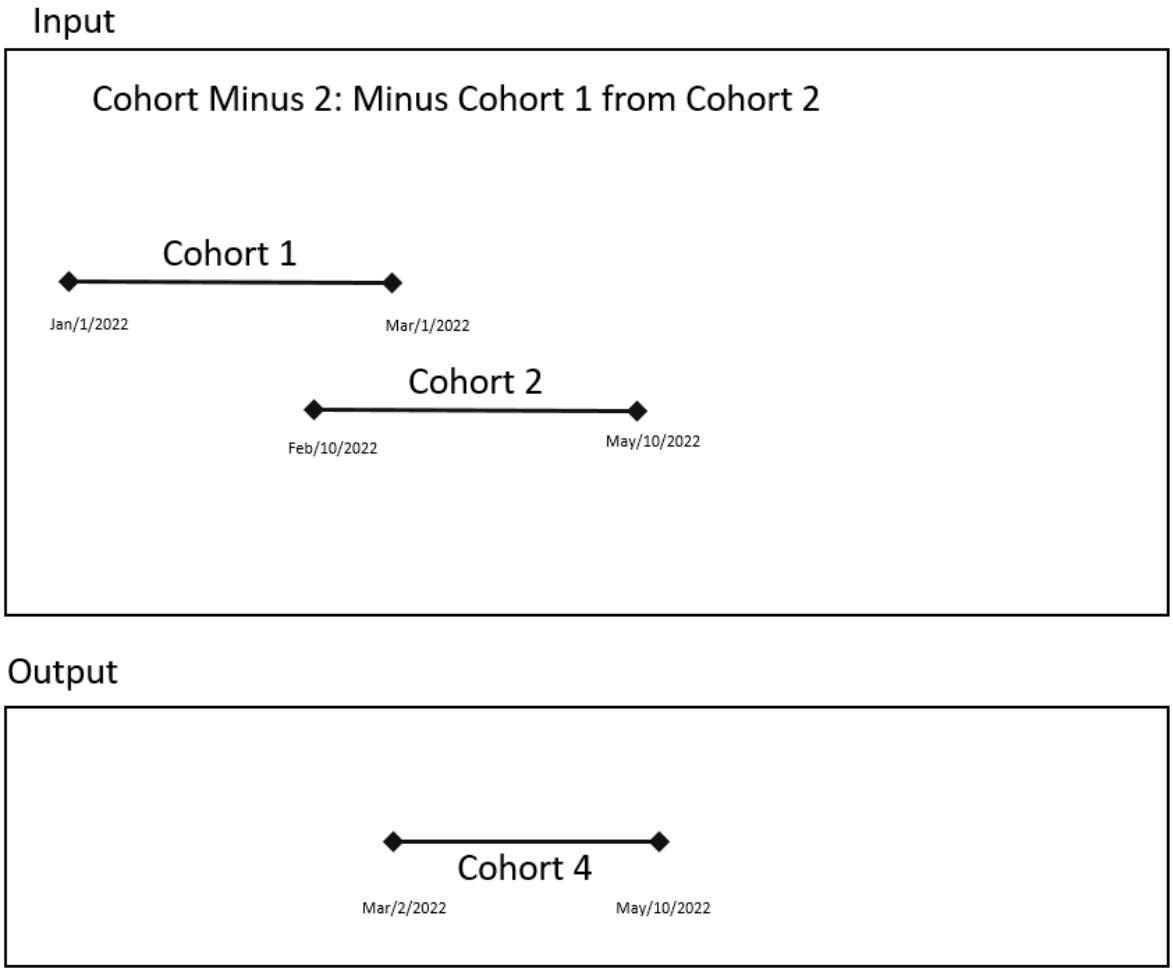


Figure 7: Cohort Minus

```
CohortAlgebra::modifyCohort(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  oldCohortId = 1,
  newCohortId = 2,
  cohortStartCensorDate = as.Date("1999-01-05"), # for left censor
  cohortEndCensorDate = as.Date("1999-01-25") # for right censor
)
```

Gives the following output

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  2         1 1999-01-05      1999-01-25
```

1.5.2 Example 2: Modify cohort by filtering cohort records by date range.

We can also filter an instantiated cohort and create a new cohort by filtering the original cohort by date ranges. This may be applied to cohort_start_date, cohort_end_date or both. Lets take this cohort as an example:

```
#> # A tibble: 2 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  3         3 2010-01-01      2010-01-05
#> 2                  3         3 1999-01-15      1999-01-25
```

We can filter by cohort_start_date using the parameter cohortStartFilterRange as follows:

```
CohortAlgebra::modifyCohort(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  oldCohortId = 3,
  newCohortId = 2,
  cohortStartFilterRange = c(as.Date("1998-01-01"), as.Date("1999-12-31")),
  purgeConflicts = TRUE
)
```

Gives the following output. Note only records where the cohort_start_date was within the given date range became cohortId 2.

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  2         3 1999-01-15      1999-01-25
```

1.5.3 Example 3: Pad cohorts by adding/substracting days from cohort start or end date.

We can add or subtracts days to an instantiated cohort and create a new cohort. Lets take this cohort as an example:

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 1999-01-01      1999-01-31
```

We can pad days as follows:

```
CohortAlgebra::modifyCohort(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cdmDatabaseSchema = cohortDatabaseSchema,
  cohortTable = tableName,
  oldCohortId = 1,
  newCohortId = 2,
  purgeConflicts = TRUE,
  cohortStartPadDays = -10,
  cohortEndPadDays = 5
)
```

Notes: because padding days may extend cohort period outside the observation_period (which is not allowed), this function will require access to the cdmDatabaseSchema and the observation_period table.

1.6 Remove subjects from Cohort

If you need to remove subjects from one or more cohorts, who are present in one or more of other cohorts - this can be achieved using this function.

```
#> Connecting using PostgreSQL driver
```

lets suppose we have a cohort table with following data:

```
#> # A tibble: 3 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  1         1 1999-01-01      1999-01-31
#> 2                  1         2 2010-01-01      2010-01-05
#> 3                  3         2 1999-01-15      1999-01-25
```

and we decide to remove from cohort id 1, all subjects in cohort id 3, and create a new cohort with cohort id 6. `removeOverlappingSubjects` can do this.We expect the output cohort 6, to not have any subjects with subjectId = 2 because subjectId 2 is present in cohort id 3.

```
CohortAlgebra::removeOverlappingSubjects(
  connection = connection,
  cohortDatabaseSchema = cohortDatabaseSchema,
  cohortId = 1,
```

```
  newCohortId = 6,
  cohortsWithSubjectsToRemove = c(3),
  purgeConflicts = FALSE,
  cohortTable = tableName
)
```

```
#> # A tibble: 1 x 4
#>   cohortDefinitionId subjectId cohortStartDate cohortEndDate
#>                <dbl>     <dbl> <date>          <date>
#> 1                  6         1 1999-01-01      1999-01-31
```