



Working with Unspecified, Approximate, Uncertain, Sets and Ranges of Dates with **messydates**

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Abstract

This paper presents the **messydates** package for R, which facilitates working with ‘messy’ dates. Messy dates are common when studying historical and sometimes even current phenomena, and can create various technical problems for the data analyst. The paper highlights these problems and offers practical advice on how to solve them using **messydates**. The paper also introduces a conceptual framework for resolving messydates into more familiar date classes in R ready for analysis.

Keywords: dates, ISO, R.

1. Introduction

Dates are often messy. Whether historical (or ancient), future, or even recent, we often only know approximately when an event occurred, that it happened within a particular period, an unreliable source means a date should be flagged as uncertain, or sources offer multiple, competing dates.

messydates implements for R the Extended Date/Time Format (EDTF) annotations set by the International Organization for Standardization (ISO) outlined in [ISO 8601-2_2019\(E\)](#). The standardised extended format allow for unambiguous interpretation of dates and guarantee interoperability. These include notation for:

- unspecified date(component)s, e.g. 2012-XX-01 for the first of some unknown month in 2012 or 2012-01 for some unknown day in January 2012
- approximate date(component)s, e.g. 2012-01-12~ for approximately the 12th of Jan-

uary 2012

- uncertain date(component)s, e.g. 2012-01-12? where this data point is based on an unreliable source
- sets of dates, e.g. {2012-01-01, 2012-01-12} where the date can be either 1 January 2012 and 12 January 2012
- ranges of dates, e.g. 2012-01-01..2012-01-12 for all dates between the 1 January 2012 and 12 January 2012 inclusive

messydates contains a set of tools for constructing and coercing into and from the **mdate** class. This date class allows regular dates to be annotated to express unspecified, approximate or uncertain date components, date ranges, and sets of dates.

The package includes functions for expanding sets or ranges of dates into all dates consistent with how the date or set of dates are specified or annotated. Methods are also offered that can be used to make explicit how researchers convert date imprecision into precise dates for analysis, such as getting the `min()`, `max()`, or even a `random()` date from among the dates in a set or range of dates. This greatly facilitates research transparency and robustness checks as we will demonstrate below.

1.1. Motivation

As researchers, we often recognize this messiness but are required to force non-existent precision on data so we can proceed with analysis. For example, if we only know something happened in a given month or year, we might just opt for the start of that month (e.g. 2021-07-01) or year (2021-01-01), assuming that to err on the earlier (or later) side is a justifiable bias. However, this can create issues for inference in which sequence or timing is important. The goal of **messydates** is to help with this problem by retaining and working with various kinds of date imprecision.

1.2. Relationship to other packages

messydates offers a new date class, but one that comes with methods for converting from and into **base** date classes such as **Date**, **POSIXct**, and **POSIXlt**. It is thus fully compatible with packages such as **lubridate** (Grolemund and Wickham 2011) and **anytime** (Eddelbuettel 2019). **messydates** is, therefore, compatible (perhaps with an additional coercion step) with all contemporary R packages for analysis.

2. R code

2.1. A new class

messydates contains a set of tools for constructing and coercing into and from the **mdate** class. This date class implements ISO 8601-2:2019(E) and allows regular dates to be annotated to express unspecified date components, approximate or uncertain date components, date ranges, and sets of dates. The function `as_messydate()` handles the coercion to the **mdate** class.

```
R> tibble::tribble(~Example, ~Date,
+                  "A normal date", as.character(Sys.Date()),
```

```

+           "A future date", "2599-12-31",
+           "A written date", "This is the first day of February, two thousand and t
+           "A historical date", "476",
+           "An era date", "33 BC",
+           "An approximate date", "2012-01-12~",
+           "An uncertain date", "2001-01-01?",
+           "An unspecified date", "2012-01",
+           "A censored date", "..2012-01-12",
+           "A range of dates", "2019-11-01:2020-01-01",
+           "A set of dates", "2021-5-26, 2021-11-19, 2021-12-4") %>%
+   dplyr::mutate(base = as.Date(Date),
+                 lubridate = lubridate::as_date(Date),
+                 anytime = anytime::anydate(Date),
+                 messydates = messydates::as_messydate(Date))

# A tibble: 11 x 6
  Example      Date      base      lubridate anytime      messy~1
  <chr>      <chr>      <date>      <date>      <date>      <mdate>
1 A normal date 2022-09-09 2022-09-09 2022-09-09 2022-09-09 2022-0~
2 A future date 2599-12-31 2599-12-31 2599-12-31 2599-12-31 2599-1~
3 A written date This is the fir~ NA      NA      NA      2021-0~
4 A historical date 476      NA      NA      NA      0476 ~
5 An era date 33 BC      NA      NA      NA      -0033 ~
6 An approximate date 2012-01-12~ 2012-01-12 2012-01-12 2012-01-12 2012-0~
7 An uncertain date 2001-01-01? 2001-01-01 2001-01-01 2001-01-01 2001-0~
8 An unspecified date 2012-01      NA      2020-12-01 2012-01-01 2012-0~
9 A censored date ..2012-01-12 NA      2012-01-12 NA      ..2012~
10 A range of dates 2019-11-01:2020~ 2019-11-01 2019-11-01 2019-11-01 2019-1~
11 A set of dates 2021-5-26, 2021~ 2021-05-26 NA      2021-05-26 {2021-~
# ... with abbreviated variable name 1: messydates

```

2.2. Annotate

Some datasets have, for example, an arbitrary cut off point for start and end points, but these are often coded as precise dates when they are not the real start or end dates. **messydates** helps annotate uncertainty and approximation to dates. Inaccurate start or end dates can be represented by an affix indicating “on or before”, if used as a prefix (e.g. `..1816-01-01`), or indicating “on or after”, if used as a suffix (e.g. `2016-12-31..`). Approximate dates are indicated by adding a `~` to year, month, or day components, as well as groups of components or whole dates to estimate values that are possibly correct (e.g. `2003-03-03~`). Day, month, or year, uncertainty can be indicated by adding a `?` to a possibly dubious date (e.g. `1916-10-10?`) or date component (e.g. `1916-?10-10`).

```

R> tibble::tibble(Beg = as_messydate(c("1816-01-01", "1916-01-01", "2016-01-01")),
+               End = as_messydate(c("1816-12-31", "1916-12-31", "2016-12-31"))) %>%
+   dplyr::mutate(on_or_before = ifelse(Beg <= "1816-01-01", on_or_before(Beg), Beg),

```

```

+           on_or_after = ifelse(End >= "2016-01-01", on_or_after(End), End),
+           as_approximate = ifelse(End >= "2016-01-01", on_or_after(End), End),
+           as_uncertain = ifelse(End == "1916-12-31", as_uncertain(End), End))

# A tibble: 3 x 6
  Beg      End      on_or_before on_or_after  as_approximate as_uncertain
  <mdate>  <mdate>    <chr>         <chr>         <chr>          <chr>
1 1816-01-01 1816-12-31 ..1816-01-01 1816-12-31    1816-12-31     1816-12-31
2 1916-01-01 1916-12-31 1916-01-01    1916-12-31    1916-12-31     1916-12-31?
3 2016-01-01 2016-12-31 2016-01-01    2016-12-31.. 2016-12-31..    2016-12-31

```

2.3. Expand

The `expand()` function transform date ranges, sets of dates, and unspecified or approximate dates (annotated with `'.'`, `'{ , }'`, `'XX'` or `'~'`) into lists of dates. As these dates may refer to several possible dates, the function “opens” these values to include all the possible dates implied.

```

R> dates_expand <- as_messydate(c("2001-01-01", "2001-01", "2001-01-01..2001-02-01",
+                                "{2001-01-01,2001-02-01}", "2001-XX-01"))
R> expand(dates_expand)

```

```
[[1]]
```

```
[1] "2001-01-01"
```

```
[[2]]
```

```

[1] "2001-01-01" "2001-01-02" "2001-01-03" "2001-01-04" "2001-01-05"
[6] "2001-01-06" "2001-01-07" "2001-01-08" "2001-01-09" "2001-01-10"
[11] "2001-01-11" "2001-01-12" "2001-01-13" "2001-01-14" "2001-01-15"
[16] "2001-01-16" "2001-01-17" "2001-01-18" "2001-01-19" "2001-01-20"
[21] "2001-01-21" "2001-01-22" "2001-01-23" "2001-01-24" "2001-01-25"
[26] "2001-01-26" "2001-01-27" "2001-01-28" "2001-01-29" "2001-01-30"
[31] "2001-01-31"

```

```
[[3]]
```

```

[1] "2001-01-01" "2001-01-02" "2001-01-03" "2001-01-04" "2001-01-05"
[6] "2001-01-06" "2001-01-07" "2001-01-08" "2001-01-09" "2001-01-10"
[11] "2001-01-11" "2001-01-12" "2001-01-13" "2001-01-14" "2001-01-15"
[16] "2001-01-16" "2001-01-17" "2001-01-18" "2001-01-19" "2001-01-20"
[21] "2001-01-21" "2001-01-22" "2001-01-23" "2001-01-24" "2001-01-25"
[26] "2001-01-26" "2001-01-27" "2001-01-28" "2001-01-29" "2001-01-30"
[31] "2001-01-31" "2001-02-01"

```

```
[[4]]
```

```
[1] "2001-01-01" "2001-02-01"
```

```
[[5]]
 [1] "2001-01-01" "2001-02-01" "2001-03-01" "2001-04-01" "2001-05-01"
 [6] "2001-06-01" "2001-07-01" "2001-08-01" "2001-09-01" "2001-10-01"
[11] "2001-11-01" "2001-12-01"
```

2.4. Contract

The `contract()` function operates as the opposite of `expand()`. It contracts a list of dates into their abbreviated annotations.

```
R> tibble::tibble('Original Dates' = dates_expand,
+                'Contracted Dates' = contract(expand(dates_expand)))

# A tibble: 5 x 2
  'Original Dates'      'Contracted Dates'
  <mdate>              <mdate>
1 2001-01-01           2001-01-01
2 2001-01             2001-01
3 2001-01-01..2001-02-01 2001-01-01..2001-02-01
4 {2001-01-01,2001-02-01} {2001-01-01,2001-02-01}
5 2001-XX-01           2001-XX-01
```

2.5. Coerce from messydates

Coercion functions coerce objects of `mdate` class objects to common date classes such as `Date`, `POSIXct`, and `POSIXlt`. Since `mdate` objects can hold multiple individual dates, an additional function must be passed as an argument so that multiple dates are “resolved” into a single date. For example, one might wish to use the earliest possible date in a range, or set, of expanded dates (`min`), or the latest possible date (`max`), or some notion of a central tendency (`mean`, `median`, or `modal`), or even a `random` selection from amongst the candidate dates.

```
R> tibble::tibble(min = as.Date(dates_expand, min),
+                max = as.Date(dates_expand, max),
+                median = as.Date(dates_expand, median),
+                mean = as.Date(dates_expand, mean),
+                modal = as.Date(dates_expand, modal),
+                random = as.Date(dates_expand, random))

# A tibble: 5 x 6
  min      max      median      mean      modal      random
  <date>   <date>   <date>   <date>   <date>   <date>
1 2001-01-01 2001-01-01 2001-01-01 2001-01-01 2001-01-01 2001-01-01
2 2001-01-01 2001-01-31 2001-01-16 2001-01-16 2001-01-01 2001-01-18
3 2001-01-01 2001-02-01 2001-01-17 2001-01-16 2001-01-01 2001-01-01
4 2001-01-01 2001-02-01 2001-02-01 2001-01-16 2001-01-01 2001-02-01
5 2001-01-01 2001-12-01 2001-07-01 2001-06-16 2001-01-01 2001-01-01
```

2.6. Additional functionality

Several other functions are also offered in the **messydates** package. For example, one can run various logical tests for checking **mdate** objects:

- `is_messydate()` tests whether the object inherits the **mdate** class
- `is_intersecting()` tests whether there is any intersection between two **mdate** objects
- `is_element()` similarly tests whether an **mdate** can be found within an **mdate** range or set
- `is_similar()` tests whether two **mdate** contain similar components
- `is_precise()` tests for whether **mdate** is precise

```
R> is_messydate(as_messydate("2001-01-01"))
```

```
[1] TRUE
```

```
R> is_messydate(as.Date("2001-01-01"))
```

```
[1] FALSE
```

```
R> is_intersecting(as_messydate("2001-01"), as_messydate("2001-01-01..2001-02-22"))
```

```
[1] TRUE
```

```
R> is_intersecting(as_messydate("2001-01"), as_messydate("2001-02-01..2001-02-22"))
```

```
[1] FALSE
```

```
R> is_element(as_messydate("2001-01-01"), as_messydate("2001-01"))
```

```
[1] TRUE
```

```
R> is_element(as_messydate("2001-01-01"), as_messydate("2001-02"))
```

```
[1] FALSE
```

```
R> is_similar(as_messydate("2001-06-02"), as_messydate("2001-02-06"))
```

```
[1] TRUE
```

```
R> is_similar(as_messydate("2001-06-22"), as_messydate("2001-02-06"))
```

```
[1] FALSE
```

```
R> is_precise(as_messydate("2001-06-02"))
```

```
[1] TRUE
```

```
R> is_precise(as_messydate("2001-02"))
```

```
[1] FALSE
```

Additionally, one can perform intersection (`md_intersect()`) and union (`md_union()`) on, *inter alia*, messy date class objects. Or perform a ‘join’ that retains all elements, even if duplicated, with `md_multiset`.

```
R> md_intersect(as_messydate("2001-01-01..2001-01-20"), as_messydate("2001-01"))
```

```
[1] "2001-01-01" "2001-01-02" "2001-01-03" "2001-01-04" "2001-01-05"
[6] "2001-01-06" "2001-01-07" "2001-01-08" "2001-01-09" "2001-01-10"
[11] "2001-01-11" "2001-01-12" "2001-01-13" "2001-01-14" "2001-01-15"
[16] "2001-01-16" "2001-01-17" "2001-01-18" "2001-01-19" "2001-01-20"
```

```
R> md_union(as_messydate("2001-01-01..2001-01-20"), as_messydate("2001-01"))
```

```
[1] "2001-01-01" "2001-01-02" "2001-01-03" "2001-01-04" "2001-01-05"
[6] "2001-01-06" "2001-01-07" "2001-01-08" "2001-01-09" "2001-01-10"
[11] "2001-01-11" "2001-01-12" "2001-01-13" "2001-01-14" "2001-01-15"
[16] "2001-01-16" "2001-01-17" "2001-01-18" "2001-01-19" "2001-01-20"
[21] "2001-01-21" "2001-01-22" "2001-01-23" "2001-01-24" "2001-01-25"
[26] "2001-01-26" "2001-01-27" "2001-01-28" "2001-01-29" "2001-01-30"
[31] "2001-01-31"
```

```
R> md_multiset(as_messydate("2001-01-01..2001-01-20"), as_messydate("2001-01"))
```

```
[1] "2001-01-01" "2001-01-02" "2001-01-03" "2001-01-04" "2001-01-05"
[6] "2001-01-06" "2001-01-07" "2001-01-08" "2001-01-09" "2001-01-10"
[11] "2001-01-11" "2001-01-12" "2001-01-13" "2001-01-14" "2001-01-15"
[16] "2001-01-16" "2001-01-17" "2001-01-18" "2001-01-19" "2001-01-20"
[21] "2001-01-01" "2001-01-02" "2001-01-03" "2001-01-04" "2001-01-05"
[26] "2001-01-06" "2001-01-07" "2001-01-08" "2001-01-09" "2001-01-10"
[31] "2001-01-11" "2001-01-12" "2001-01-13" "2001-01-14" "2001-01-15"
[36] "2001-01-16" "2001-01-17" "2001-01-18" "2001-01-19" "2001-01-20"
[41] "2001-01-21" "2001-01-22" "2001-01-23" "2001-01-24" "2001-01-25"
[46] "2001-01-26" "2001-01-27" "2001-01-28" "2001-01-29" "2001-01-30"
[51] "2001-01-31"
```

Some arithmetic operations are available for messydates. For instance, one can add, or subtract, a day or one year to one, or all, `mdate` objects in a vector.

```
R> tibble::tibble(date = dates_expand,
+               add = dates_expand + 1,
+               subtract = dates_expand - "1 year")
```

```
# A tibble: 5 x 3
  date          add          subtract
  <mdate>      <mdate>      <mdate>
1 2001-01-01    2001-01-02    2000-01-02
2 2001-01      2001-01-02..2001-02-01 2000-01-02..2000-02-01
3 2001-01-01..2001-02-01 2001-01-02..2001-02-02 2000-01-02..2000-02-02
4 {2001-01-01,2001-02-01} {2001-01-02,2001-02-02} {2000-01-02,2000-02-02}
5 2001-XX-01    2001-XX-02    2000-XX-02
```

2.7. Case Study - 2001 Battles

Dates, even for some recent events, can be messy. Take the dates of battles in 2001 according to [Wikipedia](#) included in **messydates**. The dates of these battles are often approximate (i.e. the day in which a battle started or ended is unknown) or come from unreliable sources (i.e. the date might not be trustworthy).

```
R> battles <- messydates::battles
R> battles
```

```
# A tibble: 20 x 3
  Battle          Date          Parties
  <chr>          <mdate>      <chr>
1 Operation MH-2    2001-03-08    MK-National Li~
2 2001 Bangladesh-India border clashes 2001-04-16..2001-04-20 BD-ID
3 Operation Vaksince 2001-05-25    MK-National Li~
4 Alkhan-Kala operation 2001-06-22..2001-06-28 RU-Chechen Rep~
5 Battle of Vedenov 2001-08-13..2001-08-26 RU-Chechen Ins~
6 Operation Crescent Wind 2001-10-7..2001-12? US/UK-Taliban
7 Operation Rhino 2001-10-19..2001-10-20 US-Taliban
8 Battle of Mazar-e-Sharif 2001-11-09    US/Northern Al~
9 Siege of Kunduz 2001-11-11..2001-11-23 US/Northern Al~
10 Battle of Herat 2001-11-12     US/Northern Al~
11 Battle of Kabul 2001-11-13..2001-11-14 US/Northern Al~
12 Battle of Tarin Kowt 2001-11-13..2001-11-14 US/Eastern All~
13 Operation Trent 2001-11-~15..2001-11-~30 US/UK-Taliban/~
14 Battle of Kandahar 2001-11-22..2001-12-07 US/AU/Eastern ~
15 Battle of Qala-i-Jangi 2001-11-25..2001-12-01 US/UK/Northern~
16 Battle of Tora Bora 2001-12-12..2001-12-17 US/Northern Al~
17 Battle of Shawali Kowt 2001-12-03    US/Eastern All~
18 Battle of Sayyd Alma Kalay 2001-12-04    US/Eastern All~
19 Battle of Amami-Oshima 2001-12-22    JP-KP
20 Tsotsin-Yurt operation 2001-12-30..2002-01-03 RU-Chechen Ins~
```

messydates facilitates working with these dates as we can, for example, check date precision, get the median values, and find the longest battle in 2001.

```
R> messydates::is_precise(battles$Date)
```



```
[1] TRUE FALSE TRUE FALSE FALSE FALSE FALSE TRUE FALSE TRUE FALSE FALSE
[13] FALSE FALSE FALSE FALSE TRUE TRUE TRUE FALSE
```

```
R> as.Date(battles$Date, median)
```

```
[1] "2001-03-08" "2001-04-18" "2001-05-25" "2001-06-25" "2001-08-20"
[6] "2001-11-19" "2001-10-20" "2001-11-09" "2001-11-17" "2001-11-12"
[11] "2001-11-14" "2001-11-14" "2001-11-23" "2001-11-30" "2001-11-28"
[16] "2001-12-15" "2001-12-03" "2001-12-04" "2001-12-22" "2002-01-01"
```

```
R> as.numeric(as.Date(battles$Date, max) - as.Date(battles$Date, min))
```

```
[1] 0 4 0 6 13 85 1 0 12 0 1 1 15 15 6 5 0 0 0 4
```

Getting the timing right can be important for researchers. This is especially true if researchers are looking to generate robust inferences. Until now, when faced with date imprecision, researchers usually have to choose between making arbitrary choices (e.g. adding “-01-01” to non-precise dates) or work with imprecise dates (e.g. year only). Either choice may lead to biased results. Assume we are interested in the relationship between the United States (US) being a party to a conflict and the duration of the conflict in 2001. We hypothesize that conflicts involving the US have a shorter duration because the US military capabilities. Using **messydates** we create two different variables representing conflict time from the 2001 battles data to be our dependent variables; one variable with arbitrary cut off points and the other variable with random values for uncertain or approximate dates. As our independent variable, we create a binary variable for whether the US was involved in the conflict. As a control, we code the number of actors in the conflict. With these variables we run two simple linear regression models.

```
R> set.seed(1301)
R> battles <- battles %>%
+   mutate(arbitrary = as.numeric(as.Date(Date, max) - as.Date(Date, min)),
+          random = ifelse(is_uncertain(Date)/is_approximate(Date),
+                          abs(as.Date(Date, random) - as.Date(Date, random)),
+                          arbitrary),
+          US_party = ifelse(grepl("US", Parties), 1, 0),
+          n_actors = c(2, 2, 2, 2, 2, 3, 2, 4, 4, 4, 3, 3, 4, 4, 5, 4, 3, 3, 2, 2))
R> lm(arbitrary ~ US_party + n_actors, battles)
```

Call:

```
lm(formula = arbitrary ~ US_party + n_actors, data = battles)
```

Coefficients:

(Intercept)	US_party	n_actors
8.815	10.802	-2.479

```
R> lm(random ~ US_party + n_actors, battles)
```

Call:

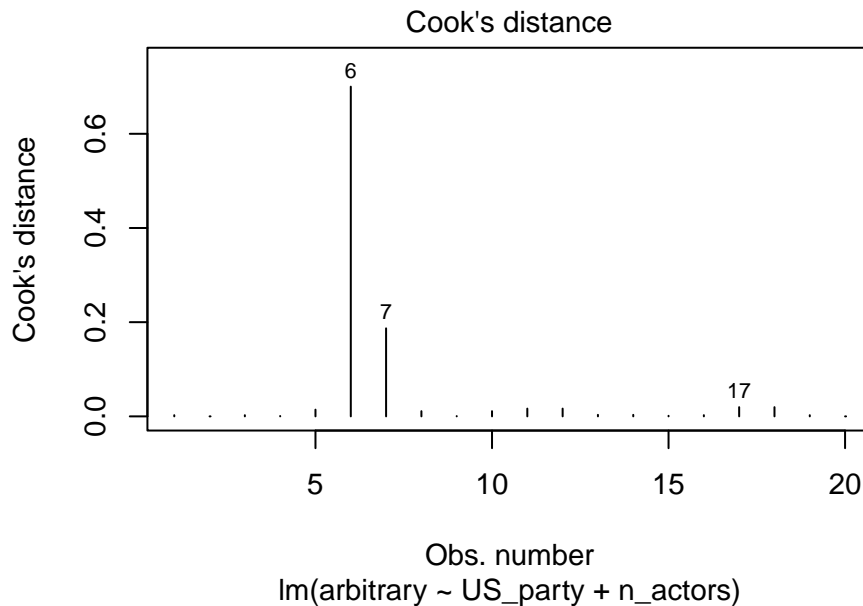
```
lm(formula = random ~ US_party + n_actors, data = battles)
```

Coefficients:

(Intercept)	US_party	n_actors
0.538	-1.410	1.660

Notice how the regression coefficients change in the two models. Although not statistically significant, the coefficient for US being a party in a conflict goes from being positive, when calculated using arbitrary cut off dates, to being negative, when calculated using random dates. In this case, setting arbitrary cut off points to dates introduces highly influential outliers (see Cook's distance below).

```
R> plot(lm(arbitrary ~ US_party + n_actors, battles), which = 4)
```



Hence, it is hard to say whether there is a relationship between the US being an actor involved in one of the battles in 2001 and its duration.

3. Acknowledgements

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