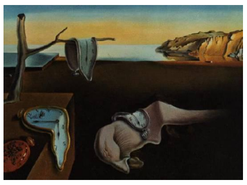

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Working with Unspecified, Approximate, Uncertain, Sets and Ranges of Dates with messydates

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Abstract

This paper presents the **messydates** package for R, which facilitates working with 'messy' dates. Messy dates are dates that include some imprecision and do not easily fit within the standard date format because they are historical, ambiguous, approximate, unspecified or uncertain, or otherwise admit of a range or set of possible dates. Messy dates are common when studying historical but also potentially current phenomena. Oftentimes, researchers will elect to pretend as if a messy date is more precise than it is to make it compatible with other more precise dates and to use various tools of temporal analysis such as event history analysis. 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

While there are several different

Messy dates include some degree of imprecision such that existing

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 January 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.

1.1. Motivation

Researchers often recognize this messiness but feel 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. Or they might opt for the end of the time element because whatever they believe happened at least is known to have happened by then. 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 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,
+                  "Normal date", as.character(Sys.Date()),
+                  "Future date", "2599-12-31",
+                  "Written date", "This is the first day of February, two thousand and twe
+                  "Historical date", "476",
+                  "Era date", "33 BC",
+                  "Approximate date", "2012-01-12~",
+                  "Uncertain date", "2001-01-01?",
+                  "Unspecified date", "2012-01",
+                  "Censored date", "..2012-01-12",
+                  "Range of dates", "2019-11-01:2020-01-01",
+                  "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 Normal date      2022-10-24           2022-10-24 2022-10-24 2022-10-24 2022-1~
 2 Future date      2599-12-31           2599-12-31 2599-12-31 2599-12-31 2599-1~
 3 Written date     This is the first ~ NA         NA         NA         2021-0~
 4 Historical date  476                  NA         NA         NA         0476  ~
 5 Era date         33 BC                NA         NA         NA         -0033 ~
 6 Approximate date 2012-01-12~          2012-01-12 2012-01-12 2012-01-12 2012-0~
 7 Uncertain date   2001-01-01?          2001-01-01 2001-01-01 2001-01-01 2001-0~
 8 Unspecified date 2012-01              NA         2020-12-01 2012-01-01 2012-0~
 9 Censored date    ..2012-01-12         NA         2012-01-12 NA         ..2012~
10 Range of dates   2019-11-01:2020-01~ 2019-11-01 2019-11-01 2019-11-01 2019-1~
11 Set of dates     2021-5-26, 2021-11~ 2021-05-26 NA         2021-05-26 {2021-~
# ... with abbreviated variable name 1: messydates
```

2.2. Recognition

2.3. 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
```

2.4. Expand

The 'expand()´ function transforms 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 "expands" these shorthands 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"
```

2.5. 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
```

2.6. 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 2001-01-26
3 2001-01-01 2001-02-01 2001-01-17 2001-01-16 2001-01-01 2001-01-06
4 2001-01-01 2001-02-01 2001-02-01 2001-01-16 2001-01-01 2001-01-01
5 2001-01-01 2001-12-01 2001-07-01 2001-06-16 2001-01-01 2001-10-01
```

2.7. 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 the result would contain duplicates, 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
```

2.8. 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$precise <- is_precise(battles$Date)
R> battles

# A tibble: 20 x 4
   Battle                              Date                      Parties precise
   <chr>                               <mdate>                   <chr>   <lgl>
 1 Operation MH-2                      2001-03-08                MK-Nat~ TRUE
 2 2001 Bangladesh-India border clashes 2001-04-16..2001-04-20   BD-ID   FALSE
 3 Operation Vaksince                  2001-05-25                MK-Nat~ TRUE
 4 Alkhan-Kala operation               2001-06-22..2001-06-28    RU-Che~ FALSE
 5 Battle of Vedeno                    2001-08-13..2001-08-26    RU-Che~ FALSE
 6 Operation Crescent Wind             2001-10-7..2001-12?       US/UK-~ FALSE
 7 Operation Rhino                     2001-10-19..2001-10-20    US-Tal~ FALSE
 8 Battle of Mazar-e-Sharif            2001-11-09                US/Nor~ TRUE
 9 Siege of Kunduz                     2001-11-11..2001-11-23    US/Nor~ FALSE
10 Battle of Herat                     2001-11-12                US/Nor~ TRUE
11 Battle of Kabul                     2001-11-13..2001-11-14    US/Nor~ FALSE
12 Battle of Tarin Kowt                2001-11-13..2001-11-14    US/Eas~ FALSE
13 Operation Trent                     2001-11-~15..2001-11-~30  US/UK-~ FALSE
14 Battle of Kandahar                  2001-11-22..2001-12-07    US/AU/~ FALSE
15 Battle of Qala-i-Jangi              2001-11-25..2001-12-01    US/UK/~ FALSE
16 Battle of Tora Bora                 2001-12-12..2001-12-17    US/Nor~ FALSE
```

```
17 Battle of Shawali Kowt                2001-12-03                US/Eas~ TRUE
18 Battle of Sayyd Alma Kalay            2001-12-04                US/Eas~ TRUE
19 Battle of Amami-Oshima                2001-12-22                JP-KP   TRUE
20 Tsotsin-Yurt operation                2001-12-30..2002-01-03    RU-Che~ FALSE
```

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> 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 of 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
```

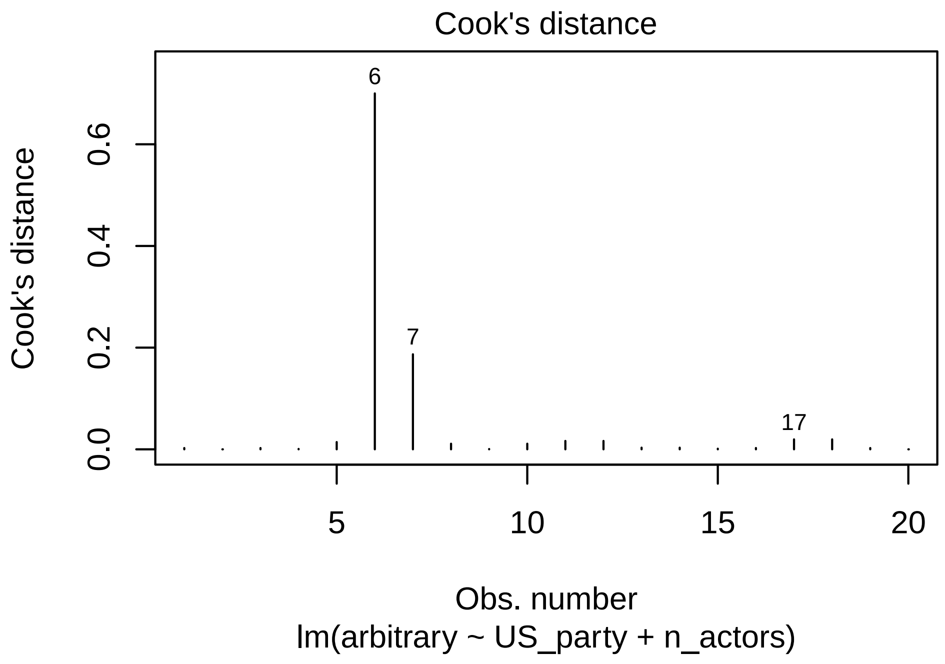
```
R> lm(random ~ US_party + n_actors, battles)
```

```
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 and even flip signs 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. Conclusion

4. Acknowledgements

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