CHIC402/CHIC602 Coursework 2 - Variant Analysis

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This project focuses on the analysis of the United Kingdom's genetically-typed SARS-CoV-2 infections data. The data set summarises the weekly infections fractions of 17 SARS-CoV-2 variants, starting *2021-01-31*, and ending *2021-10-17*; additionally, there's the field *Other*, each value of this field represents a pooled fraction w.r.t. (with respect to) an unknown number of unnamed variants.

Each week has 2 fractions records: one for cases associated with known travel links, the other without. The sum of each record's 18 infections fractions is **1**.

1 The Data

In this document the data frame variable *variants* stores the variants' data set. It consists of

```
'data.frame': 76 obs. of  20 variables:
 $ week       : Date, format: "2021-01-31" "2021-01-31" ...
 $ travel     : Factor w/ 2 levels "none","travel": 1 2 1 2 1 2 1 2 ...
 $ Alpha      : num  0.95 0.615 0.964 0.474 ...
 $ Beta       : num  0.00128 0.07692 0.00138 0.19298 ...
 $ Delta      : num  0.000107 0 0.000231 0 ...
 $ Eta        : num  0.0016 0.07692 0.00154 0.08772 ...
 $ Gamma      : num  0.00 0.00 7.69e-05 0.00 ...
 $ Kappa      : num  0 0 0 0 ...
 $ Theta      : num  0 0 0 0 0 0 0 0 ...
 $ Zeta       : num  0.00032 0 0 0 ...
 $ Lambda     : num  0 0 0 0 ...
 $ VUI.21FEB.01: num  0.000213 0 0.000231 0 ...
 $ VOC.21FEB.02: num  0.00032 0 0.000385 0 ...
 $ VUI.21FEB.04: num  0 0.038462 0.000231 0.035088 ...
 $ VUI.21APR.03: num  0 0 0 0 0 0 0 0 ...
 $ VUI.21MAY.01: num  0 0 0 0 0 0 0 0 ...
 $ VUI.21MAY.02: num  0 0 0 0 ...
 $ VUI.21OCT.01: num  0.000107 0 0 0 ...
 $ Mu         : num  0 0 0 0 0 0 0 0 ...
 $ Other      : num  0.0458 0.1923 0.0322 0.2105 ...
```

1.1 Long Format

Some parts of this document use the long form of *variants*, stored by the variable *melted*.

```r
# The long form of data frame 'variants'
melted <- variants %>%
        tidyr::gather(key = 'variant', value = 'fraction', -c(week, travel))
```

The structure of *melted* is

```
'data.frame': 1368 obs. of  4 variables:
 $ week    : Date, format: "2021-01-31" "2021-01-31" ...
 $ travel  : Factor w/ 2 levels "none","travel": 1 2 1 2 1 2 1 2 ...
 $ variant : chr  "Alpha" "Alpha" "Alpha" ...
 $ fraction: num  0.95 0.615 0.964 0.474 ...
```

1.2 Infections Proportion Statistics by Variant

Parts of this document depend on infections proportion statistics by variant. The function *VariantsProportions( )* calculates the statistics. In the code snippet below *proportions* stores the calculations.

```r
# Infections proportion statistics
proportions <- VariantsProportions(melted = melted)
```

the variable *proportions* is a named list. The elements of *proportions* are discussed in detail at appropriate points in this document. In brief, *proportions* consists of four data frames:

```r
# The contents of the named-list variable 'proportions'; each is a  data frame.
names(proportions)
```

```
[1] "none"          "travel"        "leading"       "leadingseries"
```

The data frame *none* summarises the total contribution of each variant w.r.t. **(a)** infections without known travel links, and **(b)** the data's time span (*2021-01-31* → *2021-10-17*); the same logic applies to *travel*, for infections with travel links.

The data frame *leading* lists the 5 variants responsible for the most infections, w.r.t. both travel & non-travel linked infections, during the data's time span; *leadingseries* stores the infections' data of these five.

2 An Exploration of Non-travel Data

Each variant's weekly data consists of two records. One represents the infections-fractions associated with known travel links (denoted *travel* in field *travel*), whilst the other represents the infections-fractions without known travel links (denoted *none* in field *travel*). This section focuses on non-travel data, and the variable *local* stores the applicable data.

```r
# 3.0
# The non-travel data only
local <- variants %>%
        dplyr::filter(travel == 'none')
```

The truncated data description highlights the number of non-travel data records.

```
'data.frame':    38 obs. of  20 variables:
 $ week       : Date, format: "2021-01-31" "2021-02-07" ...
 $ travel     : Factor w/ 2 levels "none","travel": 1 1 1 1 1 1 1 1 ...
 $ Alpha      : num  0.95 0.964 0.974 0.982 ...
 $ Beta       : num  0.001278 0.001385 0.000663 0.001003 ...
 $ Delta      : num  1.07e-04 2.31e-04 2.21e-04 7.72e-05 ...
  [list output truncated]
```

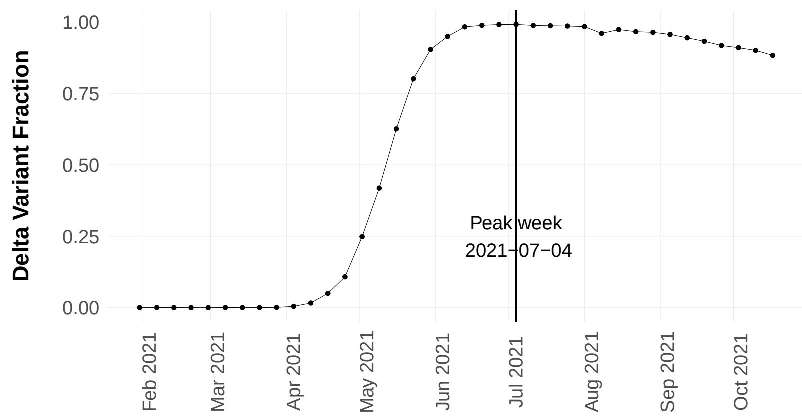
2.1 The Progression of Delta (non-travel)

A variant of interest, amongst the variants that contribute to the non-travel infections quantities, is the **Delta** variant. During the data's time span the largest proportion of non-travel infections was due to the Delta variant (*Table 1*).

Table 1: The variants responsible for the 5 largest non-travel infections proportion

variant	proportion
Delta	22.333
Alpha	14.553
VUI.21OCT.01	0.707
Beta	0.050
Kappa	0.030
VUI.21MAY.01	0.025

The graph of *Fig. 1* illustrates the progression of Delta variant infections over time. Each week's Delta fraction is a fraction of the week's total non-travel infections due to all recorded variants; named and otherwise. Delta's fractions peak at 0.991 on 2021-07-04; hereafter, it seems that the Delta fraction values are continuously, but slowly, declining.



The weekly progression of Delta variant infections over time. Each week's Delta fraction is a fraction of the week's total non−travel infections due to all recorded variants; named & other. Delta's fractions peak at 0.991 on 2021−07−04; hereafter, a slow decline seems to have started.

Figure 1: The Weekly Non-Travel Delta Variant Infections Fractions Over Time

2.2 Variant Peaks (non-travel)

In general, each variant has a fraction peak date w.r.t. the

- data's time span: *2021-01-31* → *2021-10-17*
- non-travel data

The snippet below determines the peak date of each variant, and arranges the variants in descending peak-date fraction order.

```
peaks <- local %>%
        select(!(travel)) %>%
        tidyr::gather(key = 'variant', value = 'p', -week) %>%
        group_by(variant) %>%
        slice(which.max(p)) %>%
        arrange(desc(p))
```

Hence, *Table 2* lists the peak date & peak-date fraction per variant.[1]

Table 2: The peak date and peak-date fractions; descending fraction order

Variant	Peak Date	Peak Date Fraction
Delta	2021-07-04	0.991
Alpha	2021-03-28	0.989
VUI.21OCT.01	2021-10-17	0.116
Other	2021-01-31	0.046
Kappa	2021-04-18	0.009
Beta	2021-04-25	0.008

[1]Note: `Other` is not a variant, it represents a collection of variants, therefore excluded.

Variant	Peak Date	Peak Date Fraction
VUI.21MAY.01	2021-05-09	0.007
VUI.21FEB.04	2021-04-18	0.003
Gamma	2021-04-25	0.003
Eta	2021-05-02	0.003
VUI.21MAY.02	2021-04-11	0.002
Zeta	2021-02-14	0.001
VUI.21APR.03	2021-04-18	0.001
VOC.21FEB.02	2021-02-07	0.000
Mu	2021-07-11	0.000
VUI.21FEB.01	2021-02-07	0.000
Lambda	2021-01-31	0.000
Theta	2021-01-31	0.000

3 Variant Proportions by Known/Unknown Travel Links

The section *Infections Proportion Statistics by Variant* calculates a few variant proportions, and stores the results in named-list variable *proportions*.

```
# The contents of the named-list variable 'proportions'; each is a  data frame.
names(proportions)
```

```
[1] "none"          "travel"        "leading"       "leadingseries"
```

The *proportions* data frame element *leading* lists the five variants responsible for the five largest variant-infection–proportions, w.r.t. **(a)** known & unknown travel links, and **(b)** the data's time span; *Table 3*.

Table 3: The variants responsible for the five largest variant-infection–proportions w.r.t. entire data time span

Variant	Proportion
Delta	44.1426727
Alpha	25.5222505
VUI.21OCT.01	1.1626944
Beta	1.0029552
Eta	0.6273858

3.1 The Predominant Variants

The time series of each variant of *Table 3* is illustrated in *Fig.*. The second graph has a rescaled *y-axis*, which makes it easier to observe the progression of curves that have small fraction values. A few observations:

- **In relation to infections with known travel links**, the Alpha variant dominated initially, but the Beta & Eta fractions are fairly substantive. During May 2021 the Delta variant overtook the Alpha variant - from May 2021, until the end of the data's time span, the Delta variant had the largest infections-fraction each week. By the end of the period (a) the Alpha variant barely contributes to each week's travel linked infections, and (b) the fractional contributions of VUI.21OCT.01 are increasing each week.

- **In relation to infections without known travel links**, again the Alpha variant dominated initially, and quite comprehensively; the Beta & Eta variants contribute small fractions. However, from May 2021 onward the Delta variant had the largest infections-fraction each week. In line with

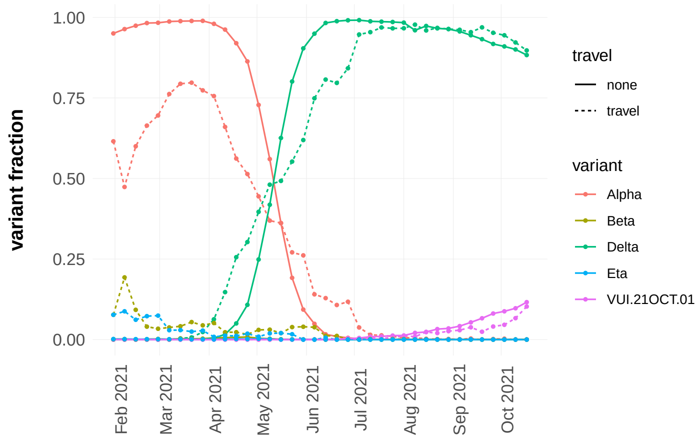


Figure 2: Weekly fraction proportions of the predominant variants listed in Table 3; w.r.t. (a) travel and non-travel infections, and (b) the data's time span. For a better view of the curves with generally small fractions, refer to Fig. 3; it is a version of this graph with a re-scaled y-axis.

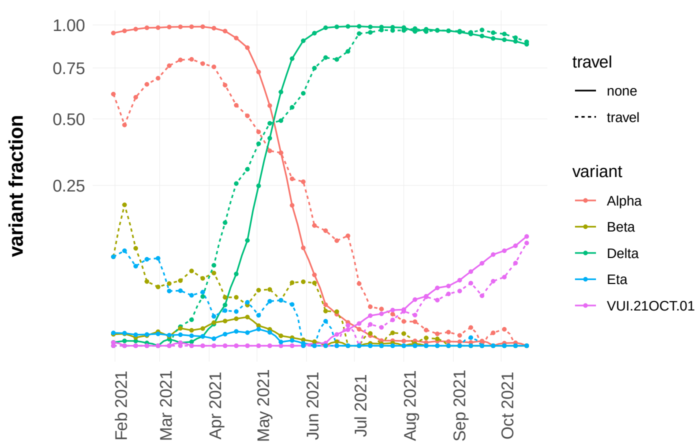


Figure 3: A version of Fig. 2 wherein the y-axis has been re-scaled, this makes it easier to observe the progression of curves that have generally small fraction values.

3.2 Progression Patterns

During the data set's time span Alpha initially dominated travel-linked & non-travel–linked infections. Its dominance is much more pronounced in the non-travel graph.

By May 2021 Delta starts contributing the largest weekly travel & non-travel infection fractions. The total travel & non-travel infection proportions due to Delta are quite similar. The fractions contributed by Delta continuously increase until the weekly fractions of VUI.21OCT.01 start becoming prominent. Thus far, the weekly travel-linked & non-travel–linked infection fractions of VUI.21OCT.01 have been relatively low.

The infections due to Beta, and those of Other (12 variants + Other), are predominantly travel linked.

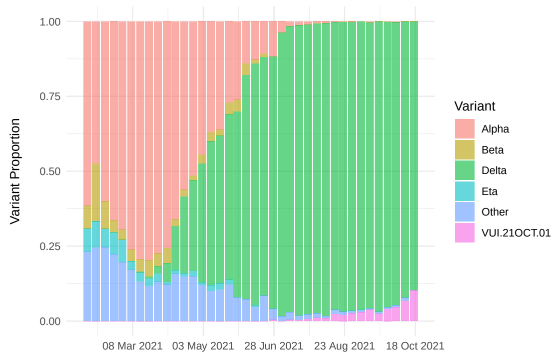


Figure 4: Progression w.r.t. travel-linked infections

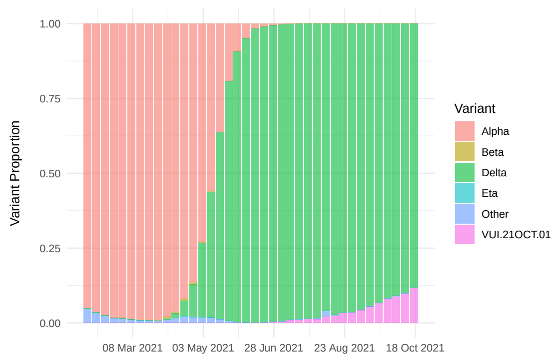


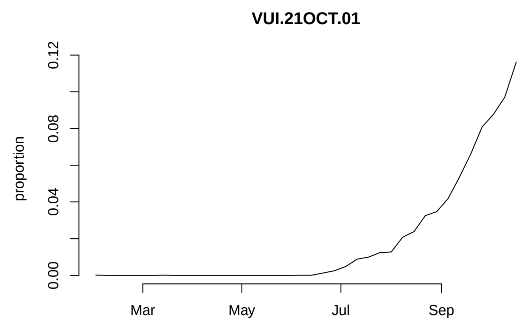
Figure 5: Infection fractions, without known travel links, over time

4 The New Variant

This chapter focuses on non-travel VUI.21OCT.01 variant data; the variable *vui21oct01* stores this data.

```
# the non-travel VUI.21OCT.01 Data
vui21oct01 <- variants %>%
        filter(travel == 'none') %>%
        select(week, 'VUI.21OCT.01')
```

4.1 Non-travel VUI.21OCT.01 Cases Over Time



4.2 A Prediction Model

An exponential growth model, for predicting daily infection fractions, has been developed. The model is

$$p = e^{(d\beta + \alpha)}$$

wherein

- $\alpha = -526.0385$
- $\beta = 0.0277$
- $d \rightarrow$ days since 1970-01-01

The function *VariantProgressionModel( )* uses this model to predict daily infection fractions w.r.t. **(a)** a start date, and **(b)** a length of time. The variable *estimates* stores the predictions w.r.t. an entire year, starting from the starting date of the non-travel VUI.21OCT.01 data.

```
starting <- min(vui21oct01$week)
period <- lubridate::years(x = 1)
estimates <- VariantProgressionModel(starting = starting, period = period)
```

The predictions for *1 September 2021* & *1 January 2022* are extracted from *estimates*; *Table 4* summarises the results. The 1 January 2022 prediction is implausible because it is > 1; herein, a prediction should not exceed 1 because it is a fraction, and it can only equal 1 if, and only if, no other variant exist.

Table 4: Predictions for 1 September 2021 & 1 January 2022

	date	prediction
214	2021-09-01	0.036
336	2022-01-01	1.070

4.3 Prediction Curve