Analysis of COVID-19 infections in Kuwait

These projections are made using publicly available data which may not be accurate for the purposes of these projections

Ahmed Bou-Rabee
August 12th, 2020
Data visualization

Forecasts
  Regression

Estimating $R_t$

CDC endorsed international models
Current daily cases

Figure 1: total daily confirmed COVID-19 infections
Daily cases and tests

Figure 2: total daily tests and confirmed cases
Figure 3: total number of positive cases per day against the total number of tests per day
Weekly new cases

**Figure 4:** weekly number of new COVID-19 infections.
**Daily new cases**

*Figure 5: daily number of new COVID-19 infections*
Three-day moving average
One-week moving average
Two-week moving average
Data visualization

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Estimating $R_t$

CDC endorsed international models
we have $N$ data points, where $N$ is the total number of days since the infection began

$y_1, y_2, \ldots, y_N$

we assume there is an approximate relation between the number of days since first infection $x = \{1, 2, \ldots\}$, the number of previous infections reported, and the total number of new infections, $y_i \approx f(x_i; y_{i-1}, y_{i-1}, \ldots, y_1)$

for each function type, exponential, sigmoid, etc, we determine best possible fit to the data, $\hat{f}$

specifically, we use optimization to determine $\hat{f}$ so that

$$\sum_{i=1}^{N}(\hat{f}(x_i) - y_i)^2$$

is minimized
we want $y \approx \hat{f}(x)$ in the future

to check this, we reserve the last week as a test set, leaving the rest as a training set

we can assess model performance by root-mean-squared prediction error (RMSE) on the test set

we do this for Kuwait data for several different models
Regression on infections - training

Regressive fits on cumulative incidence - train data

- Truth
- Yesterday + number of new cases yesterday
- Exponential fit
- Regression + autoregressive fit to residuals
- Richard's curve
Prediction results for infections

- tested on the last week

Regressive fits on cumulative incidence - test data

- Truth
- Yesterday + number of new cases yesterday
- Exponential fit
- Regression + autoregressive fit to residuals
- Richard's curve
Prediction results for infections

- RMSE for predictors on the last week of infections

<table>
<thead>
<tr>
<th>predictor</th>
<th>RMS error</th>
</tr>
</thead>
<tbody>
<tr>
<td>new cases today is same as yesterday</td>
<td>6592</td>
</tr>
<tr>
<td>exponential regression</td>
<td>374738</td>
</tr>
<tr>
<td>exponential regression + residual auto-regressive</td>
<td>174</td>
</tr>
<tr>
<td>richard’s curve</td>
<td>11775</td>
</tr>
<tr>
<td>baseline</td>
<td>65936</td>
</tr>
</tbody>
</table>
### Forecast for next week of daily new infections

<table>
<thead>
<tr>
<th>Date</th>
<th>Yesterday</th>
<th>Exponential</th>
<th>Autoregressive</th>
<th>Richard</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 12</td>
<td>687</td>
<td>20994</td>
<td>548</td>
<td>1709</td>
</tr>
<tr>
<td>August 13</td>
<td>687</td>
<td>22131</td>
<td>699</td>
<td>1743</td>
</tr>
<tr>
<td>August 14</td>
<td>687</td>
<td>23329</td>
<td>807</td>
<td>1778</td>
</tr>
<tr>
<td>August 15</td>
<td>687</td>
<td>24591</td>
<td>894</td>
<td>1813</td>
</tr>
<tr>
<td>August 16</td>
<td>687</td>
<td>25923</td>
<td>966</td>
<td>1850</td>
</tr>
<tr>
<td>August 17</td>
<td>687</td>
<td>27326</td>
<td>1065</td>
<td>1887</td>
</tr>
<tr>
<td>August 18</td>
<td>687</td>
<td>28805</td>
<td>1193</td>
<td>1925</td>
</tr>
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</table>
Data visualization

Forecasts
Regression

Estimating $R_t$

CDC endorsed international models
What is $R_t$?

- The reproduction number, $R$, is the average number of secondary cases of disease caused by a single infected individual over his or her infectious period.
- It is time and situation specific.
- In theory, if $R_t$ is above 1, the virus will spread quickly, if it is below 1, the virus will stop spreading.
- We estimate $R_t$ for infection spread among Kuwait as an aggregate.
- Algorithm used is (Cori, Ferguson, et. al 2013) with serial interval following a Gamma distribution with mean 6.48 days and standard deviation of 3.83 days.
$R_t$ for Kuwait is currently (8/11) estimated to be between (1.02, 1.09)
Data visualization

Forecasts
  Regression

Estimating $R_t$

CDC endorsed international models
COVID-19 forecasting

- forecasts based on statistical or mathematical models include
  - estimated deaths due to COVID-19
  - reported infections
  - hospital resource use
  - social distancing
  - reproductive ratio $R_t$

- different international teams generate predictions using various types of data (e.g. cases, demographics, mobility reports), methods, and estimates of the impacts of interventions (e.g. social distancing, use of face coverings)

- every team predicts cumulative deaths and infections, some teams include more
8 Center for Disease Control (CDC) endorsed organizations have produced COVID-19 forecasts for Kuwait:

- Auquan Data Science
- Imperial College, London
- Institute of Health Metrics and Evaluation
- Los Alamos National Laboratory
- Massachusetts Institute of Technology
- University of Geneva
- University of Southern California
- Youyang Gu

Past model performance

<table>
<thead>
<tr>
<th>Weekly Deaths</th>
<th>June 3</th>
<th>June 10</th>
<th>June 17</th>
<th>June 24</th>
<th>July 1</th>
<th>July 8</th>
<th>July 15</th>
<th>July 19</th>
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<tbody>
<tr>
<td>IHME</td>
<td>45</td>
<td>45</td>
<td>31</td>
<td>31</td>
<td>25</td>
<td>21</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td>MIT</td>
<td>123</td>
<td>117</td>
<td>77</td>
<td>59</td>
<td>52</td>
<td>39</td>
<td>73</td>
<td>21</td>
</tr>
<tr>
<td>Imperial</td>
<td>44</td>
<td>67</td>
<td>47</td>
<td>28</td>
<td>25</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>YYG</td>
<td>37</td>
<td>56</td>
<td>49</td>
<td>26</td>
<td>26</td>
<td>13</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Geneva</td>
<td>21</td>
<td>45</td>
<td>25</td>
<td>19</td>
<td>23</td>
<td>9</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>LANL</td>
<td>24</td>
<td>34</td>
<td>46</td>
<td>30</td>
<td>34</td>
<td>25</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>USC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1:** Model predictions against actual new weekly deaths due to COVID-19 in Kuwait. Predictions are generated one week prior to indicated date. Note Auquan provides forecasts for Kuwait but was removed from consideration to its consistent poor performance.
Past model performance

<table>
<thead>
<tr>
<th>Weekly Deaths</th>
<th>July 26</th>
<th>August 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHME</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>MIT</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>LANL</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Imperial</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>USC</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td>YYG</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Geneva</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 2: Model predictions against actual new weekly deaths due to COVID-19 in Kuwait. Predictions are generated one week prior to indicated date.
One week forecast

Table 3: Model predictions for new deaths for the week of August 9th.

<table>
<thead>
<tr>
<th>Model</th>
<th>New deaths this week</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHME</td>
<td>49</td>
</tr>
<tr>
<td>MIT</td>
<td>32</td>
</tr>
<tr>
<td>LANL</td>
<td>23</td>
</tr>
<tr>
<td>Imperial</td>
<td>22</td>
</tr>
<tr>
<td>USC</td>
<td>19</td>
</tr>
<tr>
<td>YYG</td>
<td>26</td>
</tr>
<tr>
<td>Geneva</td>
<td>22</td>
</tr>
</tbody>
</table>
## Long-term forecast

<table>
<thead>
<tr>
<th>Model</th>
<th>Total COVID-19 deaths by September 20th</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHME</td>
<td>800</td>
</tr>
<tr>
<td>MIT</td>
<td>523</td>
</tr>
<tr>
<td>LANL</td>
<td>554</td>
</tr>
<tr>
<td>USC</td>
<td>560</td>
</tr>
<tr>
<td>YYG</td>
<td>628</td>
</tr>
</tbody>
</table>

**Table 4:** Model predictions for cumulative detected deaths by September 20th due to COVID-19 in Kuwait.
$R_t$ for August 9th

<table>
<thead>
<tr>
<th>Model</th>
<th>$R_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial</td>
<td>0.88 (0.54 - 1.38)</td>
</tr>
<tr>
<td>University of Geneva</td>
<td>0.95 (0.99 - 1.03)</td>
</tr>
<tr>
<td>USC</td>
<td>0.95</td>
</tr>
<tr>
<td>YYG</td>
<td>1.00 (0.88 - 1.18)</td>
</tr>
</tbody>
</table>
Model name: Auquan

Intervention Assumptions: These projections do not make specific assumptions about which interventions have been implemented or will remain in place.

Methods: Fitted SEIR model

Output: Deaths, infections

Website link: https://covid19-infection-model.auquan.com/
Model name: Imperial

Intervention Assumptions: These projections do not make specific assumptions about which interventions have been implemented or will remain in place.

Methods: Ensembles of mechanistic transmission models, fit to different parameter assumptions

Output: 1 week ahead infections, $R_t$

Model assumptions and output: Institute of Health Metrics and Evaluation

Model name: IHME

Intervention Assumptions: Projections are adjusted to reflect differences in aggregate population mobility and community mitigation policies.

Methods: Combination of a mechanistic disease transmission model and a curve-fitting approach

Output: Total deaths, daily infections, testing, hospital resource use, social distancing measures

Website link: https://covid19.healthdata.org/united-states-of-america
Model assumptions and output: Los Alamos

**Model name:** LANL

**Intervention Assumptions:** This model assumes that currently implemented interventions and corresponding reductions in transmission will continue, resulting in an overall decrease in the growth rate of COVID-19. Over the course of the forecast, the model assumes that the rate of growth will decrease over time.

**Methods:** Statistical dynamical growth model accounting for population susceptibility

**Output:** Deaths, infections

**Website:** https://covid-19.bsvgateway.org/
Model assumptions and output: MIT

Model name: MIT

Intervention Assumptions: The projections assume that current interventions will remain in place indefinitely

Methods: SEIR model fit to reported death and case counts

Output: Deaths, infections, active infections, hospitalizations

Website: https://www.covidanalytics.io/projections
Model assumptions and output: University of Geneva

Model name: Geneva

Intervention Assumptions: The projections assume that social distancing policies in place at the date of calibration are extended for the future weeks.

Methods: Exponential and linear statistical models fit to the recent growth rate of cumulative deaths.

Output: Deaths, infections, $R_t$.

Website: https://renkulab.shinyapps.io/COVID-19-Epidemic-Forecasting/
Model name: USC

Intervention Assumptions: These projections assume that current interventions will remain unchanged during the forecasted period.

Methods: SIR Model.

Output: Deaths, infections, $R_t$.

Website: https://scc-usc.github.io/ReCOVER-COVID-19/#
Model name: YYG

Intervention Assumptions: The model accounts for reopenings and their impact on infections and deaths.

Methods: SEIS mechanistic model

Output: Deaths, infections, $R_t$

Website link: https://covid19-projections.com/kuwait