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Type Package

Title Predict Epidemic Curves with Generalized SEIR Modeling

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Imports pracma, minpack.lm, nlsr, ggplot2

Description Performs generalized Susceptible-Exposed-Infected-Recovered (SEIR) modeling to predict epidemic curves. The method is described in Peng et al. (2020) <[doi:10.1101/2020.02.16.20023465](https://doi.org/10.1101/2020.02.16.20023465)>.

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Contents

checkRates	2
fit_SEIQRDP	3
getA	6
getDataCOVID	7
getKappaFun	8
getLambdaFun	9
kappaFun	10
lambdaFun	11
modelFun	11

plot_SEIQRDP	12
predict_SEIQRDP	13
RK4	15
SEIQRDP	16
SEIQRDP_for_fitting	19

Index	21
--------------	-----------

checkRates	<i>Check Rates</i>
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Description

This function compares the fitted and calculated death and recovered ratios. The idea is to check whether the approximation of these ratios is appropriate.

Usage

```
checkRates(time, Q, R, D, kappaFun, lambdaFun, kappa, lambda, dt = 1)
```

Arguments

time	time vector
Q	time histories of the quarantined/active cases
R	time histories of the recovered cases
D	time histories of the deceased cases
kappaFun	anonymous function approximating the death rate
lambdaFun	anonymous function approximating the recovery rate
kappa	mortality rate
lambda	cure rate
dt	a time step, default is 1/24. This oversample time to ensure that the algorithm converges.

Value

plots for death rate and recovery rate

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. “Epidemic analysis of COVID-19 in China by dynamical modeling”, arXiv preprint arXiv:2002.06563.

<https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting>

See Also[SEIQRDP fit_SEIQRDP](#)

`fit_SEIQRDP`*Fit SEIQRDP function*

Description

Fit SEIQRDP function parameters used in the SEIQRDP function, used to model the time-evolution of an epidemic outbreak.

Usage

```
fit_SEIQRDP(  
  Q,  
  R,  
  D,  
  Npop,  
  E0,  
  I0,  
  time,  
  alpha = 0.05,  
  dt = 1/24,  
  guess,  
  ftol = sqrt(.Machine$double.eps),  
  ptol = sqrt(.Machine$double.eps),  
  gtol = 0,  
  diag = list(),  
  epsfcn = 0,  
  factor = 100,  
  maxfev = integer(),  
  maxiter = 1000,  
  nprint = 1,  
  trace = TRUE,  
  ...  
)
```

Arguments

Q	time histories of the active cases
R	time histories of the recovered cases
D	time histories of the deceased cases
Npop	total population of the country
E0	initial number of exposed cases
I0	initial number of predicted infectious cases

time	a time vector
alpha	type I error rate, default is 0.05
dt	the time step. This oversamples time to ensure that the algorithm converges
guess	initial guess parameters
ftol	nls.lm.control object. non-negative numeric. Default is 1e-6
ptol	nls.lm.control object. non-negative numeric. Default is 1e-6
gtol	nls.lm.control object. non-negative numeric. Default is 1e-6
diag	nls.lm.control object. a list or numeric vector containing positive entries that serve as multiplicative scale factors for the parameters.
epsfcn	nls.lm.control object. Default is 0.001
factor	nls.lm.control object. Default is 100
maxfev	nls.lm.control object. Default is 1000
maxiter	nls.lm.control object. Default is 100
nprint	nls.lm.control object. Default is 1
trace	set TRUE to trace iteration results
...	further arguments

Value

a list of optimized parameters

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. "Epidemic analysis of COVID-19 in China by dynamical modeling", arXiv preprint arXiv:2002.06563.

[https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting-](https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting)

See Also

[SEIQRDP predict_SEIQRDP](#)

Examples

```
start = "01/01/21"
finish = "04/01/21"
country = "Italy"
dt = 1
f=30
```

```
covidData = getDataCOVID(start = start, finish = finish, country = country)
Recovered = covidData$tableRecovered
Deaths = covidData$tableDeaths
```

```

Confirmed = covidData$tableConfirmed

if(nrow(Recovered) == 1){
  name = Recovered$CountryRegion
}else{
  name = paste0(Recovered$ProvinceState, " (",Recovered$CountryRegion,")")
}

recovered = Recovered[,5:ncol(covidData$tableRecovered)]
deaths = Deaths[,5:ncol(covidData$tableDeaths)]
confirmed = Confirmed[,5:ncol(covidData$tableConfirmed)]

Npop = 60000000

alpha_guess = 0.05
beta_guess = 0.8
LT_guess = 7
Q_guess = 0.8
lambda_guess = c(0.01,0.001,10)
kappa_guess = c(0.001,0.001,10)

guess = list(alpha_guess,
             beta_guess,
             1/LT_guess,
             Q_guess,
             lambda_guess[1],
             lambda_guess[2],
             lambda_guess[3],
             kappa_guess[1],
             kappa_guess[2],
             kappa_guess[3])

Q0 = confirmed[1]-recovered[1]-deaths[1]
I0 = 0.3*Q0
E0 = 0.3*Q0
R0 = recovered[1]
D0 = deaths[1]

Active = confirmed-recovered-deaths
Active[Active<0] <- 0

Q=Active
R=recovered
D = deaths

time = seq(as.Date(start, format = "%m/%d/%y"), as.Date(finish, format = "%m/%d/%y"), by = "1 day")

params = fit_SEIQRDP(Q = Active, R = recovered, D = deaths, Npop = Npop, E0 = E0, I0 = I0,
                    time = time, alpha = 0.05, dt = dt, guess = guess, ftol = 1e-6,
                    ptol = 1e-6, gtol = 1e-6, epsfcn = 0.001, factor = 100, maxfev = 1000,
                    maxiter = 100, nprint = 1, trace = TRUE)

```

getA	<i>Compute the matrix A</i>
------	-----------------------------

Description

This function computes the matrix A that is found in: $dY/dt = A*Y + F$

Usage

```
getA(alpha, gamma, delta, lambda, kappa)
```

Arguments

alpha	protection rate
gamma	inverse of the average latent time
delta	rate of people entering in quarantine
lambda	cure rate
kappa	mortality rate

Value

The matrix A that is found in: $dY/dt = A*Y + F$

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. "Epidemic analysis of COVID-19 in China by dynamical modeling", arXiv preprint arXiv:2002.06563.

[https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting-](https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting)

See Also

[SEIQRDP fit_SEIQRDP](#)

getDataCOVID *Get COVID-19 Data*

Description

The function collects the updated COVID-19 data from the John Hopkins University.

Usage

```
getDataCOVID(country, start = NULL, finish = NULL)
```

Arguments

country	name of the country. It should be a character string.
start	a start date in mm/dd/yy format. Start date can not be earlier than 01/22/20. Start date can not be later than finish date. If start date is NULL then start date will be 01/22/20.
finish	a finish date in mm/dd/yy format. Finish date can not be earlier than start date. If finish date is NULL then finish date will be the latest date at John-Hopkins CSSE system.

Value

a list of COVID-19 historical data including confirmed, death and recovered cases in desired time ranges.

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. "Epidemic analysis of COVID-19 in China by dynamical modeling", arXiv preprint arXiv:2002.06563.

<https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting>

See Also

[SEIQRDP fit_SEIQRDP](#)

Examples

```
 covidData = getDataCOVID(country = "Italy",
                          start = "05/01/20",
                          finish = "12/31/20")
 recovered = covidData$tableRecovered
 deaths = covidData$tableDeaths
 confirmed = covidData$tableConfirmed
```

 getKappaFun

Estimate Death Rate

Description

This function provides a first estimate of the death rate, to facilitate convergence of the main algorithm.

Usage

```
getKappaFun(
  tTarget,
  Q,
  D,
  guess,
  ftol,
  ptol,
  gtol,
  epsfcn,
  factor,
  maxfev,
  maxiter,
  nprint,
  trace
)
```

Arguments

tTarget	time vector
Q	target time-histories of the quarantined cases
D	target time-histories of the dead cases
guess	initial guess parameters for kappa
ftol	nls.lm.control object. non-negative numeric. Default is 1e-6
ptol	nls.lm.control object. non-negative numeric. Default is 1e-6
gtol	nls.lm.control object. non-negative numeric. Default is 1e-6
epsfcn	nls.lm.control object. Default is 0.001
factor	nls.lm.control object. Default is 100
maxfev	nls.lm.control object. Default is 1000
maxiter	nls.lm.control object. Default is 100
nprint	nls.lm.control object. Default is 1
trace	Set TRUE to trace iteration results

Value

vector of estimation and optimization function for the death rate

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. “Epidemic analysis of COVID-19 in China by dynamical modeling”, arXiv preprint arXiv:2002.06563.

<https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting->

See Also

[SEIQRDP fit_SEIQRDP](#)

getLambdaFun

Estimate Recovery Rate

Description

This function provides a first estimate of the recovery rate, to facilitate convergence of the main algorithm.

Usage

```
getLambdaFun(  
    tTarget,  
    Q,  
    R,  
    guess,  
    ftol,  
    ptol,  
    gtol,  
    epsfcn,  
    factor,  
    maxfev,  
    maxiter,  
    nprint,  
    trace  
)
```

Arguments

tTarget	target time vector
Q	target time-histories of the quarantined cases
R	target time-histories of the recovered cases
guess	initial guess parameters for kappa
ftol	nls.lm.control object. non-negative numeric. Default is 1e-6
ptol	nls.lm.control object. non-negative numeric. Default is 1e-6
gtol	nls.lm.control object. non-negative numeric. Default is 1e-6
epsfcn	nls.lm.control object. Default is 0.001
factor	nls.lm.control object. Default is 100
maxfev	nls.lm.control object. Default is 1000
maxiter	nls.lm.control object. Default is 100
nprint	nls.lm.control object. Default is 1
trace	set TRUE to trace iteration results

Value

vector of estimation and optimization function for the recovery rate

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. “Epidemic analysis of COVID-19 in China by dynamical modeling”, arXiv preprint arXiv:2002.06563.

<https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting>

See Also

[SEIQRDP fit_SEIQRDP](#)

kappaFun

Anonymous function approximating the death rate

Description

Anonymous function approximating the death rate

Usage

kappaFun(a, t)

Arguments

a	parameter vector
t	time vector

Value

No return value, called for side effects

lambdaFun	<i>Anonymous function approximating the recovery rate</i>
-----------	---

Description

Anonymous function approximating the recovery rate

Usage

lambdaFun(a, t)

Arguments

a	parameter vector
t	time vector

Value

No return value, called for side effects

modelFun	<i>Model function</i>
----------	-----------------------

Description

Model function

Usage

modelFun(Y, A, K)

Arguments

Y	time vector
A	the matrix A that is found in: $dY/dt = A*Y + F$
K	the zero matrix for the seven states

Value

No return value, called for side effects

plot_SEIQRDP

Plots for Epidemic Curves

Description

This function creates plots for reported and predicted active, recovered and death cases.

Usage

```
plot_SEIQRDP(
  object,
  reported = TRUE,
  sep = FALSE,
  show = c("S", "E", "I", "Q", "R", "D", "P"),
  ci = FALSE,
  title = NULL,
  checkRates = FALSE,
  ...
)
```

Arguments

object	a predict_SEIQRDP result.
reported	a logical argument. If TRUE reported official cases will be added to the plot.
sep	a logical argument. If TRUE separate plots will be plotted. If FALSE one plot with all desired states will be plotted.
show	select one or more desired state. S: Susceptible, E: Exposed, I: Infectious, Q: Quarantined, R: Recovered, D: Dead, P: Insusceptible
ci	a logical argument. If TRUE a bootstrap confidence interval will be added to the plot.
title	an optional title for the plot.
checkRates	if TRUE compares the fitted and calculated death and recovered ratios through plots
...	other plot options

Value

plots for epidemic curves: active cases, recovered and deaths

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

See Also[SEIQRDP fit_SEIQRDP](#)**Examples**

```
alpha_guess = 0.45
beta_guess = 1
LT_guess = 2
Q_guess = 0.55
lambda_guess = c(0.01,0.01,30)
kappa_guess = c(0.01,0.001,30)

guess = list(alpha_guess,
             beta_guess,
             1/LT_guess,
             Q_guess,
             lambda_guess[1],
             lambda_guess[2],
             lambda_guess[3],
             kappa_guess[1],
             kappa_guess[2],
             kappa_guess[3])

pred = predict_SEIQRDP(country = "Germany", start = "10/15/20", finish = "12/15/20",
                      dt = 1, f = 30, conf = 0.95, Npop = 80000000, guess, boot = TRUE,
                      seed = 123, repeatNumber = 10, bootSample = NULL, type = "norm")

plot_SEIQRDP(object = pred, sep = FALSE, ci = TRUE, show = c("Q", "R", "D"), checkRates = TRUE)
```

predict_SEIQRDP

Predict cases using generalized SEIR model

Description

This function predicts cases of an outbreak using a generalized SEIR model

Usage

```
predict_SEIQRDP(
  country,
  start,
  finish,
  Npop = NULL,
  guess,
```

```

dt = 1,
f = 0,
boot = FALSE,
conf = 0.95,
seed = 123,
repeatNumber = 200,
bootSample = NULL,
type = "norm"
)

```

Arguments

country	name of the country. It should be a character string.
start	a start date in mm/dd/yy format. Start date can not be earlier than 01/22/20. Start date can not be later than finish date. If start date is NULL then start date will be 01/22/20.
finish	a finish date in mm/dd/yy format. Finish date can not be earlier than start date. If finish date is NULL then finish date will be the latest date at John-Hopkins CSSE system.
Npop	total population of the country
guess	initial guess parameters
dt	the time step. This oversamples time to ensure that the algorithm converges
f	number of days for future predictions
boot	if TRUE bootstrap will be performed to calculate confidence interval
conf	confidence level, default is 0.95.
seed	set a seed for reproducible results.
repeatNumber	number of iteration for bootstrap.
bootSample	number of sample for each bootstrap. if NULL then the number of sample is 80 percent of the original data.
type	a confidence interval type. If "norm" it calculates based on normal approximation, if "perc" it calculates based on percentile approximation,

Value

a list of predicted and actual cases.

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. "Epidemic analysis of COVID-19 in China by dynamical modeling", arXiv preprint arXiv:2002.06563.

<https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting>

See Also

[SEIQRDP fit_SEIQRDP](#)

Examples

```
alpha_guess = 0.45
beta_guess = 1
LT_guess = 2
Q_guess = 0.55
lambda_guess = c(0.01,0.01,30)
kappa_guess = c(0.01,0.001,30)

guess = list(alpha_guess,
             beta_guess,
             1/LT_guess,
             Q_guess,
             lambda_guess[1],
             lambda_guess[2],
             lambda_guess[3],
             kappa_guess[1],
             kappa_guess[2],
             kappa_guess[3])

pred = predict_SEIQRDP(country = "Germany", start = "10/15/20", finish = "12/15/20",
                       dt = 1, f = 30, conf = 0.95, Npop = 80000000, guess, boot = FALSE,
                       seed = 123, repeatNumber = 100, bootSample = NULL, type = "norm")

predict = pred$pred
actual = pred$actual
```

 RK4

Runge-Kutta 4th Order Method to Solve Differential Equation

Description

Runge-Kutta 4th Order Method to Solve Differential Equation

Usage

```
RK4(Y, A, K, dt)
```

Arguments

Y	initial values for seven states
A	the matrix A that is found in: $dY/dt = A*Y + F$
K	the zero matrix for the seven states
dt	the time step. This oversamples time to ensure that the algorithm converges

Value

ordinary differential equation result for the seven states

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

<https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting->

See Also

[SEIQRDP](#) [fit_SEIQRDP](#)

SEIQRDP

Simulate generalized SEIR model

Description

This function simulates the time-histories of an epidemic outbreak using a generalized SEIR model

Usage

```
SEIQRDP(  
    alpha,  
    beta,  
    gamma,  
    delta,  
    lambda0,  
    kappa0,  
    Npop,  
    E0,  
    I0,  
    Q0,  
    R0,  
    D0,  
    lambdaFun,  
    kappaFun,  
    tstart,  
    tfinish,  
    dt = 1/24,  
    f = 0  
)
```


Arguments

alpha	fitted protection rate
beta	fitted infection rate
gamma	fitted Inverse of the average latent time
delta	fitted rate at which people enter in quarantine
lambda0	fitted cure rate
kappa0	fitted mortality rate
Npop	Total population of the sample
E0	Initial number of exposed cases
I0	Initial number of infectious cases
Q0	Initial number of quarantined cases
R0	Initial number of recovered cases
D0	Initial number of dead cases
lambdaFun	anonymous function giving the time-dependant recovery rate
kappaFun	anonymous function giving the time-dependant death rate
tstart	start date
tfinish	finish date
dt	the time step. This oversamples time to ensure that the algorithm converges
f	number of days for future predictions

Value

a list of predicted cases including susceptible, exposed, infectious, quarantined, recovered, dead and insusceptible.

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. "Epidemic analysis of COVID-19 in China by dynamical modeling", arXiv preprint arXiv:2002.06563.

[https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting-](https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting)

See Also

[fit_SEIQRDP](#)

Examples

```

start = "01/01/21"
finish = "04/01/21"
country = "Italy"
dt = 1
f=30

covidData = getDataCOVID(start = start, finish = finish, country = country)
Recovered = covidData$tableRecovered
Deaths = covidData$tableDeaths
Confirmed = covidData$tableConfirmed

if(nrow(Recovered) == 1){
  name = Recovered$CountryRegion
}else{
  name = paste0(Recovered$ProvinceState, " (",Recovered$CountryRegion,")")
}

recovered = Recovered[ ,5:ncol(covidData$tableRecovered)]
deaths = Deaths[ ,5:ncol(covidData$tableDeaths)]
confirmed = Confirmed[ ,5:ncol(covidData$tableConfirmed)]

Npop = 60000000

alpha_guess = 0.05
beta_guess = 0.8
LT_guess = 7
Q_guess = 0.8
lambda_guess = c(0.01,0.001,10)
kappa_guess = c(0.001,0.001,10)

guess = list(alpha_guess,
             beta_guess,
             1/LT_guess,
             Q_guess,
             lambda_guess[1],
             lambda_guess[2],
             lambda_guess[3],
             kappa_guess[1],
             kappa_guess[2],
             kappa_guess[3])

Q0 = confirmed[1]-recovered[1]-deaths[1]
I0 = 0.3*Q0
E0 = 0.3*Q0
R0 = recovered[1]
D0 = deaths[1]

Active = confirmed-recovered-deaths
Active[Active<0] <- 0

Q=Active

```

```

R=recovered
D = deaths

time = seq(as.Date(start, format = "%m/%d/%y"), as.Date(finish, format = "%m/%d/%y"), by = "1 day")

params = fit_SEIQRDP(Q = Active, R = recovered, D = deaths, Npop = Npop, E0 = E0, I0 = I0,
  time = time, dt = dt, guess = guess, ftol = 1e-6, ptol = 1e-6, gtol = 1e-6,
  epsfcn = 0.001, factor = 100, maxfev = 1000, maxiter = 100, nprint = 1,
  trace = TRUE)

res = SEIQRDP(alpha = params$alpha1, beta = params$beta1,
  gamma = params$gamma1, delta = params$delta1,
  lambda0 = c(params$lambda01, params$lambda02, params$lambda03),
  kappa0 = c(params$kappa01, params$kappa02, params$kappa03),
  Npop, E0, I0, Q0, R0, D0, lambdaFun = params$lambdaFun,
  kappaFun = params$kappaFun, tstart = start, tfinish = finish,
  dt = dt, f =f)

```

SEIQRDP_for_fitting *Fitted Results for SEIQRDP*

Description

Fitted Results for SEIQRDP

Usage

```
SEIQRDP_for_fitting(par, t, t0, Npop, E0, I0, Q, R, D, dt)
```

Arguments

par	initial guess parameters
t	historical time vector
t0	target time vector
Npop	total population of the country
E0	initial number of exposed cases
I0	initial number of infectious cases
Q	actual number of quarantined cases
R	actual number of recovered cases
D	actual number of dead cases
dt	the time step. This oversamples time to ensure that the algorithm converges

Value

a data frame for fitted quarantined, recovered and deaths

Author(s)

Selcuk Korkmaz, <selcukorkmaz@gmail.com>

References

Peng, L., Yang, W., Zhang, D., Zhuge, C., Hong, L. 2020. “Epidemic analysis of COVID-19 in China by dynamical modeling”, arXiv preprint arXiv:2002.06563.

<https://www.mathworks.com/matlabcentral/fileexchange/74545-generalized-seir-epidemic-model-fitting>

See Also

[fit_SEIQRDP RK4](#)

Index

checkRates, 2

fit_SEIQRDP, 3, 3, 6, 7, 9, 10, 13, 15–17, 20

getA, 6

getDataCOVID, 7

getKappaFun, 8

getLambdaFun, 9

kappaFun, 10

lambdaFun, 11

modelFun, 11

plot_SEIQRDP, 12

predict_SEIQRDP, 4, 13

RK4, 15, 20

SEIQRDP, 3, 4, 6, 7, 9, 10, 13, 15, 16, 16

SEIQRDP_for_fitting, 19