

W5.AIC,ARMA,ARIMA

Yansong Liu

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AIC and Model Quality -software-estimate coefficients in models -know how to obtain technique-deepen general understanding

Time Series dataset-realization of r.v.-generating process describe-fit model -e.g.time series data-stochastic process-AR(p) model-PACF->order p

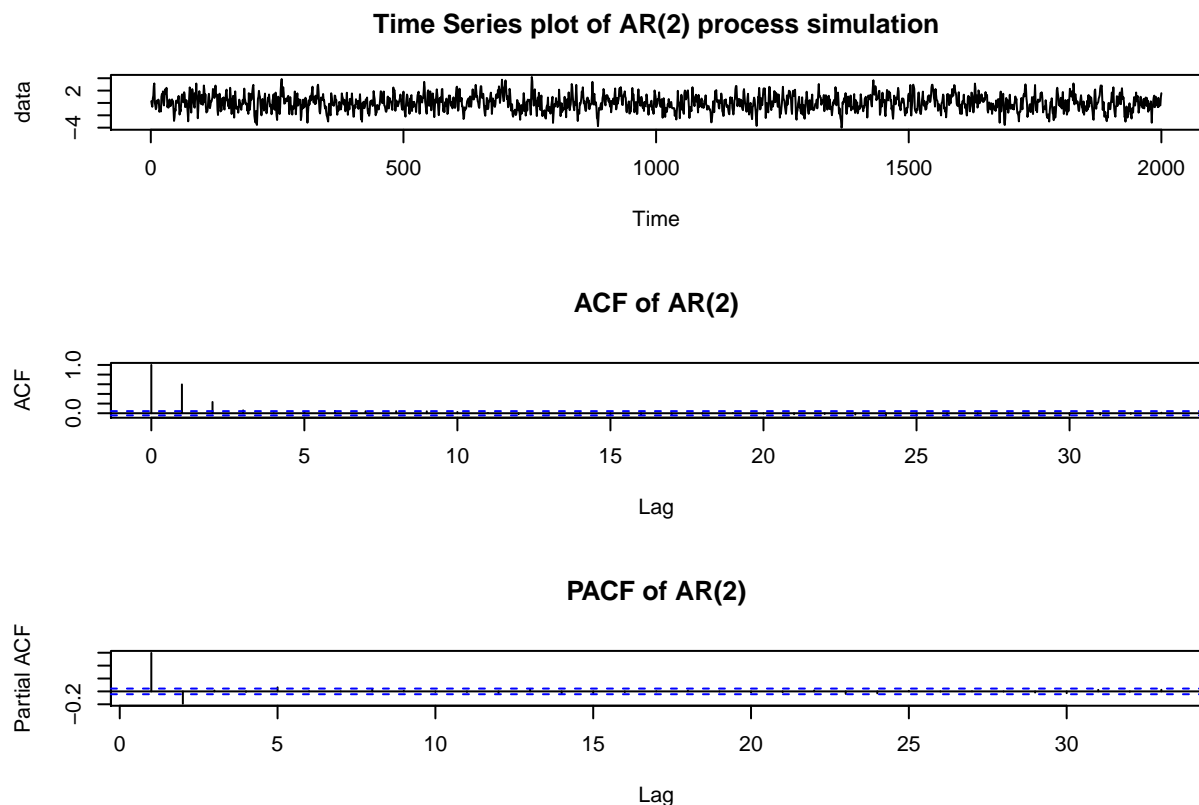
Simulate AR(2) process -complexity of nature process-AR(2) process simulation-generate data -already know the order of model-measure process behavior

```
#xt=zt+0.7*xt-1-0.2xt-2
rm(list = ls(all=TRUE))

set.seed(43)

# AR(2)-generate data points
#-arima.sim-order:(p,d,q)-AR coef-generate data points
data=arima.sim(list(order=c(2,0,0),ar=c(0.7,-0.2)),n=2000)

#plot
par(mfrow=c(3,1))
plot(data, main='Time Series plot of AR(2) process simulation')
acf(data,main='ACF of AR(2)') #cut off after lag2
acf(data, type = 'partial',main='PACF of AR(2)') # 2 spikes-2 lags
```



artificial:know coef-estimate coef-explore estimation process behavior arima:given order of process-estimate parameters AR(2)-estimate coef

numeric measurement -Loblolly Pine data(2D)-model fit-plot:straight line,parabola(better-heteroscedasticity)
 -several r.v.(nD)-candidate models-can't plot->numeric measure of quality-choose -R²:pay a penalty->high order terms of model -e.g.p=2->3:enhance in variability vs.worth 3rd order -AIC

```
#include.mean:contain constant term
arima(data, order = c(2,0,0),include.mean = FALSE)
```

```
##
## Call:
## arima(x = data, order = c(2, 0, 0), include.mean = FALSE)
##
## Coefficients:
##          ar1      ar2
##       0.7111 -0.1912
## s.e.  0.0219  0.0220
##
## sigma^2 estimated as 0.9985:  log likelihood = -2836.64,  aic = 5679.27
```

AR(p)-p,coef $x_t = z_t + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \dots + \phi_p x_{t-p}$ -predict value of x_t (t.s. at time t)-use value at p preceding time steps-order p -estimate coef.-fit a model-determine SSE,AIC

not know order of process-look ACF, PACF

AIC-access relative quality of competing models -credit:reduce SSE -penalty:bring in too many parameters

```

SSE=NULL
AIC=NULL

for (p in 1:5) {
  m=arima(data,order = c(p,0,0),include.mean = FALSE)

  SSE[p]=sum(resid(m)^2)  #sum of squared error
  AIC[p]=m$aic

  print(paste('Order of AR process,p:',p))
  print(paste('coef:',m$coef))
  print(paste('AIC:',m$aic, 'SSE:',sum(resid(m)^2)))
}

```

```

## [1] "Order of AR process,p: 1"
## [1] "coef: 0.596994815512241"
## [1] "AIC: 5751.73196762524 SSE: 2072.83193501059"
## [1] "Order of AR process,p: 2"
## [1] "coef: 0.711145701347093" "coef: -0.191155219249132"
## [1] "AIC: 5679.27375222457 SSE: 1997.00667996082"
## [1] "Order of AR process,p: 3"
## [1] "coef: 0.713593153351423" "coef: -0.200274059030527"
## [3] "coef: 0.0128196564431701"
## [1] "AIC: 5680.94495534325 SSE: 1996.67791506654"
## [1] "Order of AR process,p: 4"
## [1] "coef: 0.713676746861739" "coef: -0.201599644794246"
## [3] "coef: 0.0175530465622639" "coef: -0.00662941202904639"
## [1] "AIC: 5682.85704377107 SSE: 1996.58997811327"
## [1] "Order of AR process,p: 5"
## [1] "coef: 0.714108250773891" "coef: -0.202686722593213"
## [3] "coef: 0.0301932234553456" "coef: -0.0515469166269352"
## [5] "coef: 0.0629304752667481"
## [1] "AIC: 5676.91730818182 SSE: 1988.65973372245"

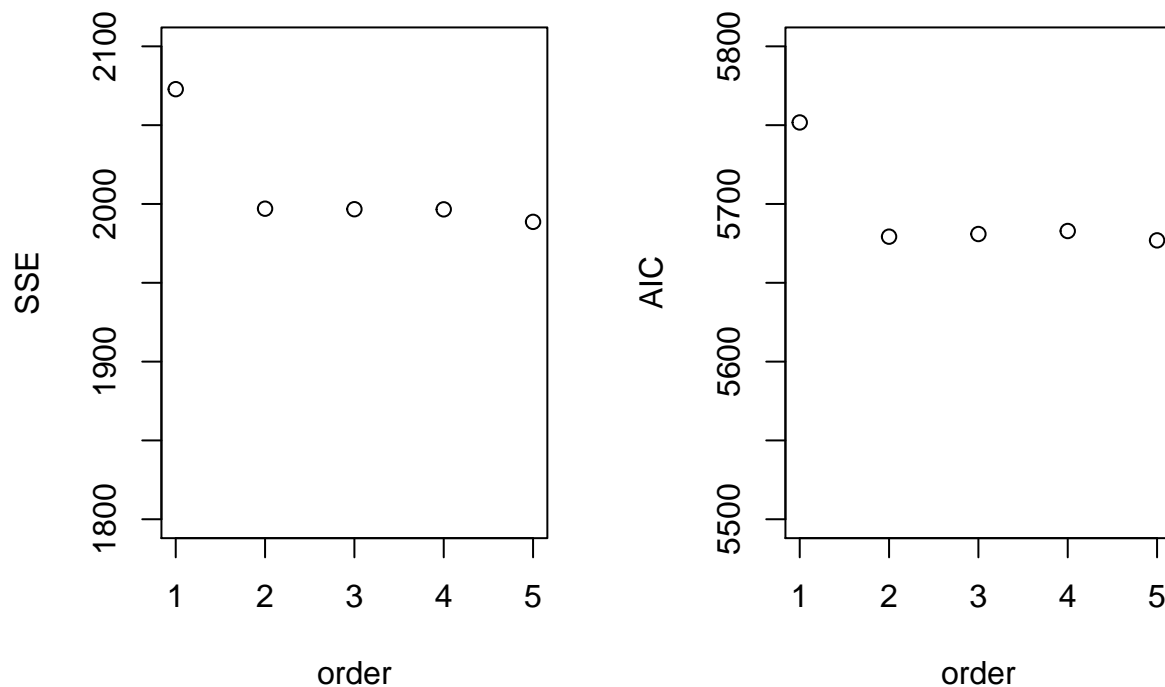
```

```

#plot trend: SSE~Order,AIC~order
par(mfrow=c(1,2))
order=c(1,2,3,4,5)
plot(SSE~order,main='SSE plotted on Order of AR(P) Model',ylim=c(1800, 2100))
plot(AIC~order,main='AIC plotted on Order of AR(P) Model',ylim=c(5500,5800))

```

SSE plotted on Order of AR(P) Model AIC plotted on Order of AR(P) Model



*# more term, SSE reduced-big drop $p=1 \rightarrow 2$
 #-after, enhancement modest-tradeoff: complexity vs. diminution of SSE*

ARMA(1,1) simulation $x_t = 0.7x_{t-1} + z_t + 0.2z_{t-1}$

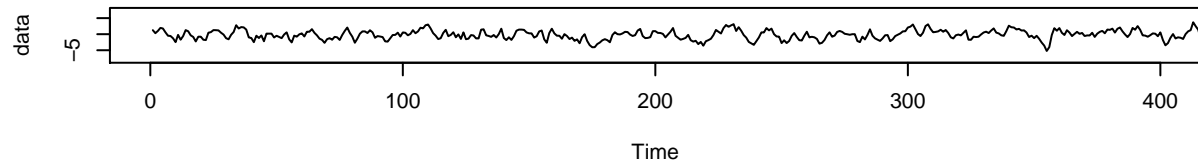
```
rm(list = ls(all=TRUE))

set.seed(500)

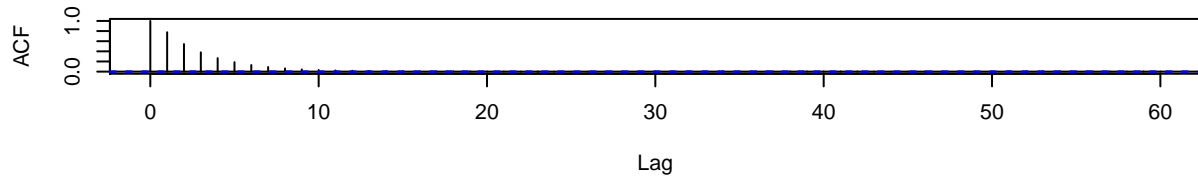
#ARMA simulation-generate data points
data=arima.sim(list(order=c(1,0,1),ar=0.7,ma=0.2),n=1000000)

# process behavior
par(mfrow=c(3,1))
plot(data,main='ARMA(1,1) Time Series:phi1=0.7,theta1=0.2',xlim=c(0,400))
acf(data,main='ACF of ARMA(1,1),phi1=0.7,theta1=0.2')
pacf(data,main='PACF of ARMA(1,1),phi1=0.7,theta1=0.2')
```

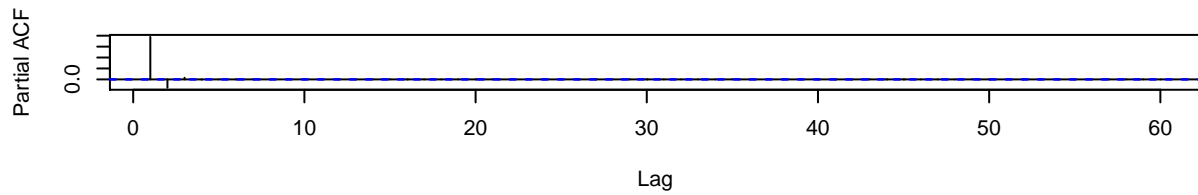
ARMA(1,1) Time Series: $\phi_1=0.7, \theta_1=0.2$



ACF of ARMA(1,1), $\phi_1=0.7, \theta_1=0.2$

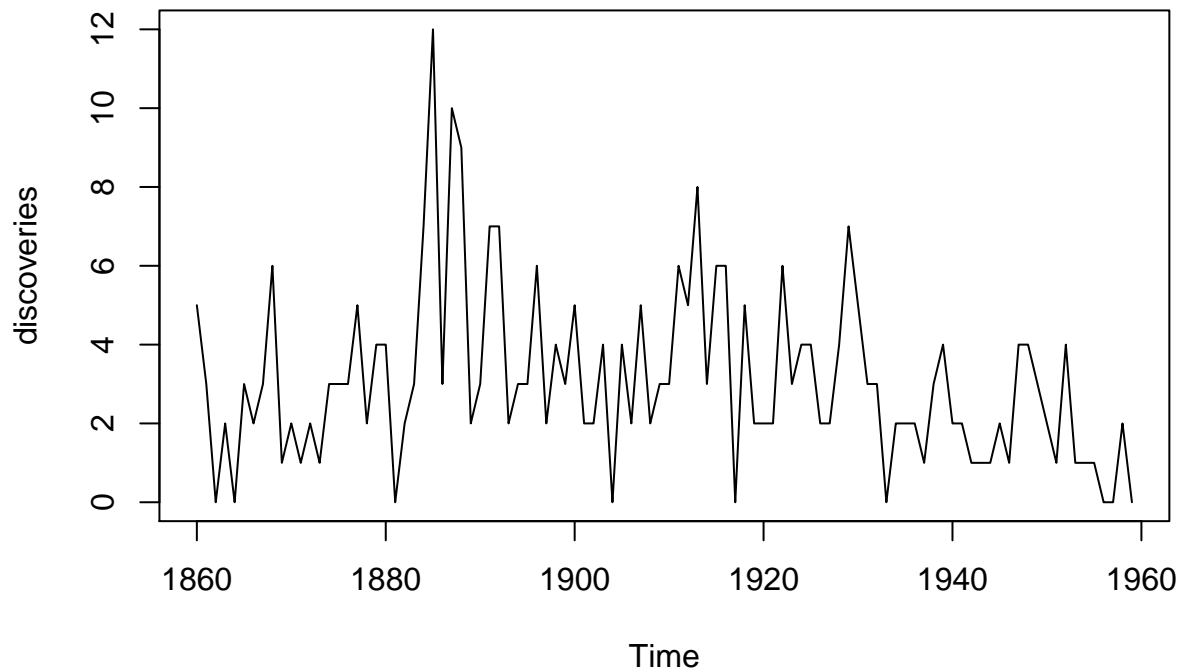


PACF of ARMA(1,1), $\phi_1=0.7, \theta_1=0.2$



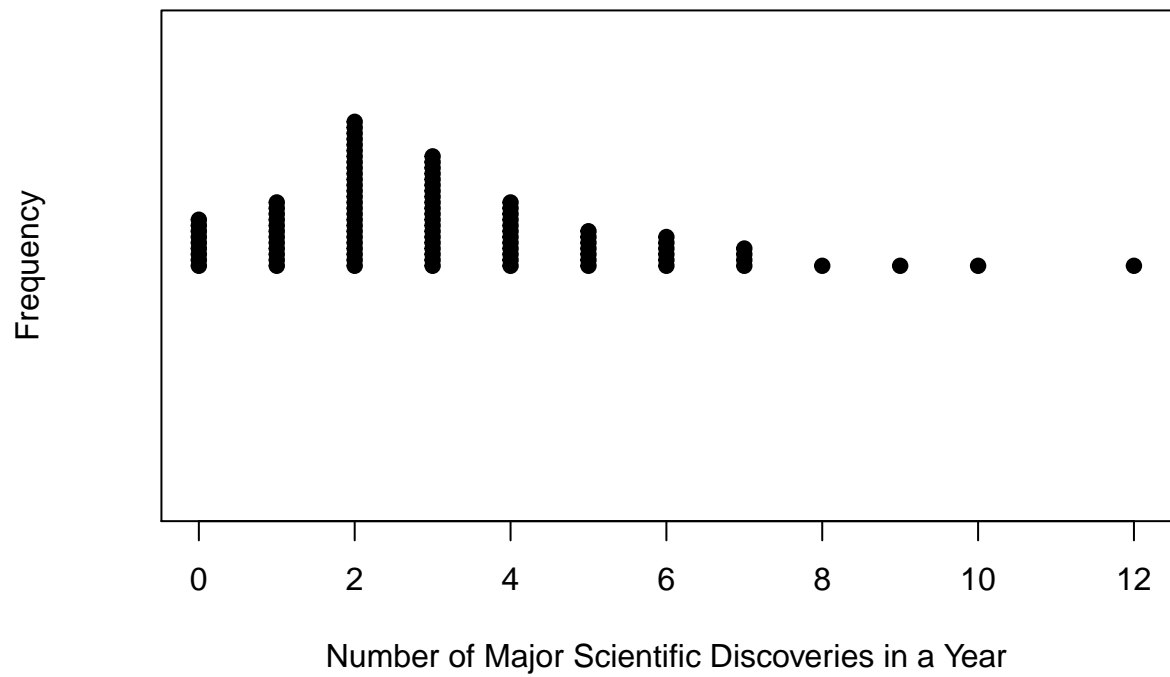
```
# typical time series
plot(discoveries,
     main='Time Series of Number of Major Scientific Discoveries in a Year')
```

Time Series of Number of Major Scientific Discoveries in a Year



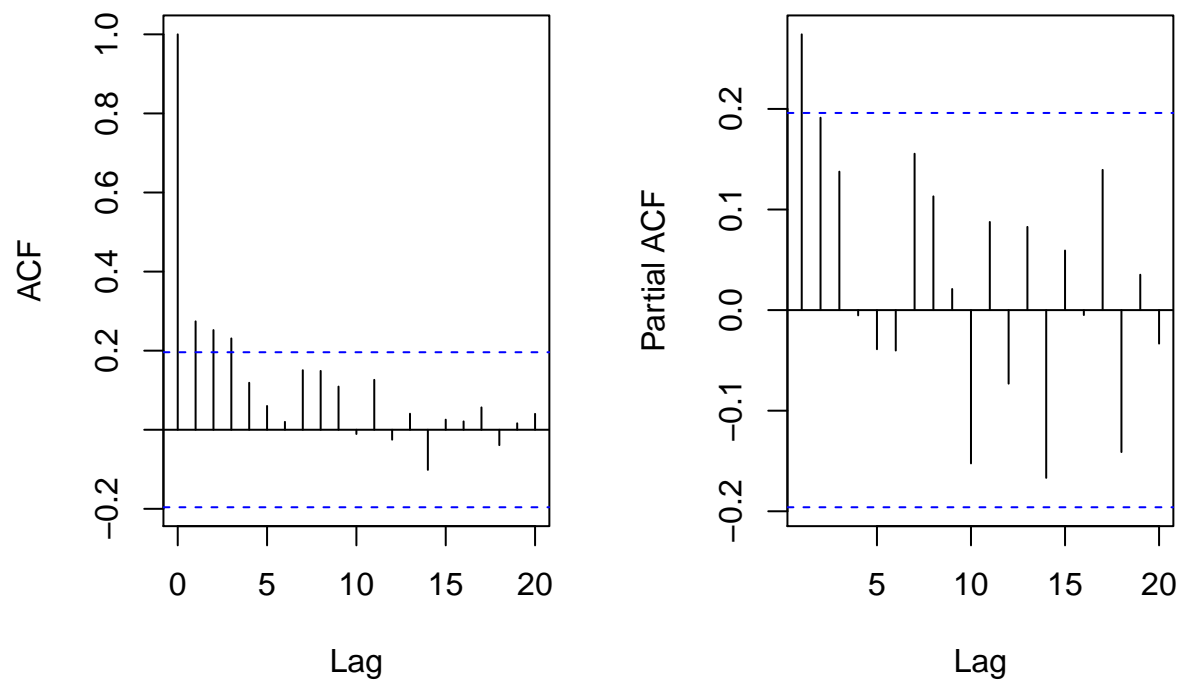
```
#stripchart-discrete data-break data out by location better-stack
stripchart(discoveries,method='stack',offset = 0.15,pch = 19,
           main='Number of Discoveries Dotplot',
           xlab = 'Number of Major Scientific Discoveries in a Year',
           ylab = 'Frequency')
```

Number of Discoveries Dotplot



```
#measure process behavior
par(mfrow=c(1,2))
acf(discoveries,main='ACF of Number of Major Scientific Discoveries in a Year') #3 spikes
acf(discoveries,type = 'partial',
    main='PACF of Number of Major Scientific Discoveries in a Year') #1 or 2 spikes
```

Number of Major Scientific Discoveries



```
arima(discoveries,order = c(1,0,1))
```

```
##
## Call:
## arima(x = discoveries, order = c(1, 0, 1))
##
## Coefficients:
##      ar1      ma1  intercept
##    0.8353 -0.6243    3.0208
## s.e. 0.1379  0.1948    0.4728
##
## sigma^2 estimated as 4.401:  log likelihood = -216.1,  aic = 440.2
```

Automatic Routines-auto.arima() -no differencing:d=0 -approximation

```
library(forecast)
```

```
## Registered S3 method overwritten by 'xts':
##   method      from
## as.zoo.xts zoo

## Registered S3 method overwritten by 'quantmod':
##   method      from
## as.zoo.data.frame zoo
```



```
## Registered S3 methods overwritten by 'forecast':
##   method          from
##   fitted.fracdiff  fracdiff
##   residuals.fracdiff fracdiff
```

```
approximation=(length(discoveries)>100|frequency(discoveries)>12)
auto.arima(discoveries,d=0,approximation = FALSE)
```

```
## Series: discoveries
## ARIMA(1,0,1) with non-zero mean
##
## Coefficients:
##          ar1      ma1      mean
##          0.8353 -0.6243  3.0208
## s.e.   0.1379   0.1948  0.4728
##
## sigma^2 estimated as 4.538:  log likelihood=-216.1
## AIC=440.2   AICc=440.62   BIC=450.62
```

```
auto.arima(discoveries,d=0,approximation = TRUE)
```

```
## Series: discoveries
## ARIMA(1,0,1) with non-zero mean
##
## Coefficients:
##          ar1      ma1      mean
##          0.8353 -0.6243  3.0208
## s.e.   0.1379   0.1948  0.4728
##
## sigma^2 estimated as 4.538:  log likelihood=-216.1
## AIC=440.2   AICc=440.62   BIC=450.62
```

specify the criterion-return best model

```
auto.arima(discoveries,d=0,ic='bic',approximation = FALSE)
```

```
## Series: discoveries
## ARIMA(1,0,1) with non-zero mean
##
## Coefficients:
##          ar1      ma1      mean
##          0.8353 -0.6243  3.0208
## s.e.   0.1379   0.1948  0.4728
##
## sigma^2 estimated as 4.538:  log likelihood=-216.1
## AIC=440.2   AICc=440.62   BIC=450.62
```

```
auto.arima(discoveries,d=0,ic='aic',approximation = FALSE)
```

```
## Series: discoveries
## ARIMA(3,0,0) with non-zero mean
```

```
##
## Coefficients:
##          ar1      ar2      ar3      mean
##          0.1967  0.1613  0.1451  3.0637
## s.e.    0.0995  0.0998  0.1007  0.4136
##
## sigma^2 estimated as 4.556:  log likelihood=-215.78
## AIC=441.57   AICc=442.2   BIC=454.59
```

```
auto.arima(discoveries,d=0,ic='aic',approximation = TRUE)
```

```
## Series: discoveries
## ARIMA(1,0,1) with non-zero mean
##
## Coefficients:
##          ar1      ma1      mean
##          0.8353 -0.6243  3.0208
## s.e.    0.1379  0.1948  0.4728
##
## sigma^2 estimated as 4.538:  log likelihood=-216.1
## AIC=440.2   AICc=440.62   BIC=450.62
```

real-life dataset-non-stationary -systematic change in trend-remove trend-difference operator

Ljung-Box Q-statistic -fit model-pull linear part-residual -test autocorrelation or white noise -Hypothesis:H0
r.v. acf all=0-r.v.independent-white noise

Modeling -Trend->differencing -Variation in variance->transformation-log return:log-differencing -ACF-
>order of MA(q) -PACF->order of AR(p) -criteria:AIC,SSE,LBQ

ARIMA(2,1,1) Simulation

```
#paramters
phi=c(0.7,0.2)
beta=0.5
sigma=3
m=10000

#ARIMA simulation-generate data points
set.seed(5)
(Simulated.Arima=arima.sim(list(order=c(2,1,1),ar=phi,ma=beta),n=m))
```

```
## Time Series:
## Start = 1
## End = 10001
## Frequency = 1
##      [1]    0.00000000   -2.66673700   -5.15001166   -6.52584017
##      [5]   -7.37774221   -7.99952058   -9.07344408   -9.73257257
##      [9]  -11.90184162  -13.44777780  -14.50010526  -14.88227869
##     [13] -15.73273294 -14.37240776 -12.87008668 -11.85888544
##     [17] -11.41030670 -10.22893422  -9.91164534  -9.42744035
##     [21]  -7.84579157  -5.20148544  -2.15556047   0.35066847
##     [25]   2.00073256   3.20437300   4.22635667   3.15743654
##     [29]   2.75120698   3.49651247   4.48336095   5.36961197
```

##	[33]	7.05224597	8.62538030	7.98301579	6.11165073
##	[37]	5.57661869	4.51499410	4.81077739	8.21683250
##	[41]	12.09994724	14.21844317	16.60158444	17.53795219
##	[45]	18.35626001	19.40063862	20.11954819	21.90150114
##	[49]	24.76292318	26.24684302	25.55567608	25.60626811
##	[53]	26.32315792	26.58010749	27.94642917	28.20938164
##	[57]	26.54209414	26.05542579	24.07704663	20.36463279
##	[61]	16.64575285	13.98100753	12.19407591	10.92619408
##	[65]	8.75163933	7.08777173	6.11168700	4.44924032
##	[69]	2.66295980	3.24563311	5.34378464	7.10268597
##	[73]	8.18261955	9.18110570	9.91620013	9.10034378
##	[77]	7.57605692	7.09567396	7.67936367	7.85037846
##	[81]	8.63647431	9.01057713	10.36065959	11.66157219
##	[85]	13.86954630	15.83017550	17.60866647	16.71744862
##	[89]	17.38487654	18.89039150	21.75173349	24.35849838
##	[93]	25.84066258	27.02964992	28.01958482	28.87133285
##	[97]	29.17003654	27.86649195	26.43744660	24.01370372
##	[101]	19.66148009	15.21842809	11.55213372	9.83542298
##	[105]	7.61714014	6.10255124	4.46183281	4.89456236
##	[109]	5.27637940	6.03836982	7.99753876	8.74407294
##	[113]	8.74882249	8.57334461	7.97273571	8.06578945
##	[117]	7.21276091	6.71762118	6.90042397	6.59753345
##	[121]	6.61516739	6.60449678	7.84576333	10.19826966
##	[125]	12.58358876	14.11405156	16.06341699	17.98359169
##	[129]	19.36564715	21.55873896	23.08976675	24.48843693
##	[133]	26.32244240	28.70255425	31.97759594	34.84689115
##	[137]	38.06701204	42.48367714	47.45776785	52.66527790
##	[141]	57.09697093	61.82824556	66.01054574	69.52787274
##	[145]	74.17392277	79.32614861	84.70892511	90.01986743
##	[149]	94.88619958	101.36336795	107.51246397	111.34863704
##	[153]	114.35308822	115.36597586	115.30195750	114.33782408
##	[157]	109.71001687	104.14671227	100.11353406	96.10845150
##	[161]	91.59278245	86.78711881	84.15241642	83.69134349
##	[165]	82.79339643	81.39403289	81.25178063	81.76155760
##	[169]	82.12464636	82.36192924	84.04154119	84.52204799
##	[173]	83.77163839	83.46118716	83.14255775	81.60785965
##	[177]	80.29945586	79.02293599	77.47168836	76.16121728
##	[181]	74.62225702	71.24242391	66.10459179	60.47475819
##	[185]	54.36104916	49.30774122	44.90652906	39.34420284
##	[189]	33.93628818	30.06752436	26.17227121	22.44829100
##	[193]	21.29728609	21.64052453	21.50915985	19.61509799
##	[197]	16.73096659	13.61183466	9.68833132	5.09417479
##	[201]	2.19330331	1.83513933	1.93705494	0.59473633
##	[205]	-0.84509716	-1.75578818	-2.65871236	-3.40898226
##	[209]	-4.82461295	-7.36479160	-8.96560624	-10.53407973
##	[213]	-12.99543720	-14.04792459	-14.55994466	-13.27285226
##	[217]	-12.23688250	-11.81617891	-10.74126156	-9.03925222
##	[221]	-7.29024722	-5.63148132	-4.83091040	-3.34094902
##	[225]	-0.67033598	2.17652979	5.07008965	9.01159369
##	[229]	13.14308869	18.88026326	24.84254573	28.65430699
##	[233]	30.92866141	34.10890501	37.03678980	39.37710080
##	[237]	42.08007951	43.85974076	46.45437105	50.01329751
##	[241]	52.31978085	54.16990370	57.56517882	62.34669568
##	[245]	66.60981343	69.01087575	71.23422772	73.08965070

##	[249]	76.02597304	79.43170567	83.25952256	86.03767584
##	[253]	87.16500293	88.58710294	89.89403144	89.60951074
##	[257]	88.23272740	85.70902455	82.88491832	80.15931581
##	[261]	76.80139822	73.96905926	70.68174941	66.04724832
##	[265]	61.55005429	57.97449287	55.09336616	49.62110335
##	[269]	41.43713172	31.71566209	23.23340308	14.71899309
##	[273]	5.66274114	-3.21850374	-12.71500945	-21.63432051
##	[277]	-28.52427460	-36.64987395	-44.51038573	-50.56195897
##	[281]	-56.51733980	-62.21550208	-66.87961679	-69.21775812
##	[285]	-72.79667054	-76.52651537	-79.47706325	-82.98644968
##	[289]	-84.42167056	-84.68429776	-83.87668012	-83.43772233
##	[293]	-82.19746684	-81.41665755	-81.15707390	-80.40887351
##	[297]	-79.78290763	-79.20498221	-77.62538377	-77.77456643
##	[301]	-77.97476090	-78.39696863	-77.77893403	-77.33808045
##	[305]	-76.07164806	-74.05981695	-72.39495522	-68.83245303
##	[309]	-63.75906595	-58.00561358	-51.64734827	-43.95542380
##	[313]	-35.02569863	-25.76908769	-17.82140501	-11.54321181
##	[317]	-6.21672711	-1.77150688	2.40279672	5.58256133
##	[321]	9.00641926	12.73028919	13.47721614	12.79876114
##	[325]	12.68170227	11.19364483	9.00836911	6.53150057
##	[329]	4.59489661	1.50322120	-2.70189716	-6.26381739
##	[333]	-10.08170016	-14.20129170	-16.03094056	-17.68235096
##	[337]	-21.46013836	-24.39066657	-27.52513445	-31.74473658
##	[341]	-35.15907037	-38.08887332	-38.59372412	-38.86448151
##	[345]	-39.18718073	-39.33828629	-41.28218199	-43.63828649
##	[349]	-43.90744249	-43.22036459	-43.76186279	-44.35073691
##	[353]	-44.86611203	-44.71714954	-45.78023413	-46.62316770
##	[357]	-46.50047556	-47.21245070	-49.67588868	-52.03391809
##	[361]	-53.75242493	-53.57229702	-52.45874579	-50.09733162
##	[365]	-45.76184286	-40.31632557	-34.60315442	-29.65067553
##	[369]	-26.74859806	-24.47577834	-21.44638713	-17.71389439
##	[373]	-13.78158663	-8.74672575	-4.04383997	1.99922485
##	[377]	8.09677344	14.10606545	19.26257992	23.72312849
##	[381]	27.80675673	31.39733875	34.64398397	36.25060197
##	[385]	38.00673991	38.73892245	39.44817288	39.91539385
##	[389]	38.95027777	38.20483986	36.30769783	36.05912167
##	[393]	37.04220438	38.89820711	39.31506811	39.80701607
##	[397]	39.58479489	40.41261251	41.36129998	39.02273717
##	[401]	35.81918790	32.71739417	30.95973215	29.75540449
##	[405]	28.91748880	28.78722540	29.40829890	30.20072929
##	[409]	30.65712396	30.08277627	29.42868277	26.77634065
##	[413]	23.40025776	19.60612710	14.97888042	11.27601970
##	[417]	8.49709501	5.16182004	1.41097267	-2.77546360
##	[421]	-7.59251138	-10.59124384	-12.82977443	-16.07063251
##	[425]	-18.03918919	-19.56453835	-23.38595930	-27.59474503
##	[429]	-31.14847782	-33.14849217	-34.63978333	-37.37602139
##	[433]	-40.63411145	-41.92112081	-41.58088343	-41.61617591
##	[437]	-40.99062061	-39.31524291	-38.94236215	-37.97103673
##	[441]	-37.81796468	-37.38712133	-36.34084935	-34.68947415
##	[445]	-33.43983075	-33.32114134	-32.55603990	-32.07389591
##	[449]	-32.59705875	-29.84436008	-26.77158354	-22.56611008
##	[453]	-18.86161257	-15.25299418	-11.78943893	-10.22888355
##	[457]	-8.94563797	-5.71330625	-1.40820845	3.00795978
##	[461]	7.14794953	9.93207719	12.61801269	14.49430771

##	[465]	16.88637704	19.70772995	24.28251095	28.09501311
##	[469]	31.63042590	34.53875003	37.88065224	42.38610308
##	[473]	46.80107386	49.87364724	51.93778866	54.97006953
##	[477]	59.32873874	61.89317852	63.80557974	66.46663607
##	[481]	71.46012900	76.62768429	81.28891822	85.77413897
##	[485]	89.39081586	90.72412384	92.06684266	93.65902483
##	[489]	94.68819259	93.91134536	92.74177344	92.16253205
##	[493]	92.23533508	94.01164293	97.10926634	99.10808188
##	[497]	99.81220776	100.77685692	102.38041246	103.29176619
##	[501]	101.11497610	97.29142786	92.98019522	87.89978307
##	[505]	83.40936586	78.54096271	73.32897591	67.68424452
##	[509]	61.27399632	56.16422129	51.16131591	46.34978914
##	[513]	42.18432592	38.84995824	36.21654957	34.14508823
##	[517]	32.97536372	31.74356502	31.97347177	32.80593603
##	[521]	33.71184775	34.32844394	35.57645567	36.62504762
##	[525]	37.43021219	38.05914602	38.53739917	40.30072634
##	[529]	43.28522344	47.88648733	50.41667071	52.18959085
##	[533]	53.82960583	55.54118118	58.35566223	61.36456824
##	[537]	63.61111716	64.53867579	66.91956397	68.79665446
##	[541]	69.18264838	68.14010005	66.51876411	65.00543615
##	[545]	64.94881491	65.75583248	65.35167709	63.75542454
##	[549]	62.23239213	62.41722733	63.37568101	65.56912699
##	[553]	70.50722719	74.68174016	78.89117427	82.03702624
##	[557]	85.92889285	89.73608756	92.79707356	95.94098718
##	[561]	99.92130500	106.10786939	112.90749870	119.66954536
##	[565]	126.16641979	132.22646472	136.22328040	137.91051629
##	[569]	140.85032234	144.31228081	148.66370661	153.26396460
##	[573]	158.48945588	164.85661285	171.28917497	174.80631847
##	[577]	179.62158206	184.21895209	187.63116398	189.22573496
##	[581]	189.97938034	190.98704101	191.73474661	190.96682492
##	[585]	190.29305677	190.40375307	192.75313670	195.69578870
##	[589]	197.05253166	197.43679304	197.64039423	198.45866800
##	[593]	200.20427914	201.10313942	201.23327588	202.12747362
##	[597]	201.88749259	202.11960622	203.36042789	203.76688393
##	[601]	204.52703671	206.86752690	210.36033728	210.73250841
##	[605]	209.92826099	211.17039485	211.12816242	209.88061805
##	[609]	208.93821531	208.13050254	207.17740797	206.02200913
##	[613]	207.63012822	207.09424232	207.29586664	210.76508177
##	[617]	213.93538370	216.95724584	220.46369292	221.67636538
##	[621]	222.05155276	222.22609726	222.49485720	225.18695455
##	[625]	229.91317409	236.21661878	244.61549002	252.42140473
##	[629]	259.90810049	268.17173049	275.10988203	281.13042035
##	[633]	286.48817738	290.10194556	293.65537578	297.86580926
##	[637]	301.11086621	304.27272944	307.64832299	309.82004403
##	[641]	310.88864142	312.67347480	313.51174613	314.37244709
##	[645]	315.15448939	317.08799628	319.54466786	320.89921936
##	[649]	321.87374393	323.24024435	324.72622175	324.44291414
##	[653]	323.58469043	321.97275939	321.12445818	322.00768320
##	[657]	322.09969221	322.33837171	323.12038594	323.62127865
##	[661]	324.44135497	326.70615753	328.31803228	329.67986776
##	[665]	332.49800498	334.46304842	336.51586510	338.89811774
##	[669]	340.39319802	340.00230934	338.48937971	338.51539270
##	[673]	338.93739522	338.23908579	337.72724728	335.39642178
##	[677]	332.89686374	330.82776175	327.95424662	325.07013528

##	[681]	321.26255009	318.10157442	315.93369604	314.58035457
##	[685]	313.44000823	312.84440768	311.67348218	311.92898654
##	[689]	310.83892254	309.54127201	308.29765209	307.92534054
##	[693]	307.22352025	306.47822109	304.23223608	299.69900227
##	[697]	294.56985149	287.85235484	281.44580540	276.38306973
##	[701]	272.61340430	269.31069265	266.94894093	266.07276489
##	[705]	265.40304768	265.42684743	265.88432859	267.30161154
##	[709]	267.36242334	266.91186881	266.01008483	265.20029189
##	[713]	265.00835055	265.60415692	265.78888234	265.79899127
##	[717]	266.40757228	267.52660335	268.99317036	269.65598684
##	[721]	269.52187263	267.50856885	264.87374900	262.02651150
##	[725]	260.20772689	257.42696653	255.68208440	254.29998775
##	[729]	251.95045709	251.01557882	250.59923849	249.58357646
##	[733]	249.33394604	249.02574555	247.15332043	246.92270334
##	[737]	247.37061876	247.71299273	246.77011355	244.45841987
##	[741]	242.09512615	239.25972489	237.47198766	237.24781933
##	[745]	237.82929922	240.05566550	242.78266879	246.53146731
##	[749]	251.48886638	257.95985691	264.94740223	270.27326558
##	[753]	275.61057843	282.02129286	287.63638273	293.75949871
##	[757]	299.20394727	304.67164237	312.01731910	319.20734469
##	[761]	324.47671857	326.40276878	327.92037186	329.70881896
##	[765]	331.82824467	334.13558820	336.33684814	338.30247475
##	[769]	339.35460812	341.61815129	343.86025663	346.58464878
##	[773]	348.96520820	350.26201792	349.15769351	348.12361790
##	[777]	347.66898887	347.40784826	348.46125787	350.26807050
##	[781]	351.68288732	352.33085488	353.15033321	355.11572767
##	[785]	358.03823503	360.63315939	362.05711860	362.72678652
##	[789]	363.53608547	364.68411416	366.77491106	368.43144444
##	[793]	369.74301200	371.94243457	374.93657725	377.30877624
##	[797]	378.96015142	379.22331144	379.65395640	380.30465969
##	[801]	381.56108367	383.75833995	385.31278963	387.27556111
##	[805]	390.53922177	391.63706504	391.82017400	392.33839970
##	[809]	392.64929959	393.17165399	393.96954066	394.07419559
##	[813]	393.00992428	390.51148221	388.59351947	389.29360032
##	[817]	390.39945688	390.69091503	389.95276211	390.16345645
##	[821]	389.80368077	390.36289224	390.14196733	388.72046085
##	[825]	385.97892997	382.58074720	380.24411552	379.13233747
##	[829]	377.27837100	375.60131503	373.79010962	372.16358622
##	[833]	370.67908698	370.67827890	371.74435909	373.35106605
##	[837]	376.61591796	379.69113222	380.87435636	383.23566572
##	[841]	384.02115080	384.39132184	385.79120989	385.79757649
##	[845]	385.24755878	385.94403968	386.28195071	385.90100200
##	[849]	385.37731594	384.54866623	383.94553143	384.20780067
##	[853]	382.94937123	380.52161417	378.21605215	374.19759341
##	[857]	370.28945922	366.53976001	363.68124362	360.46503715
##	[861]	356.74523158	350.85144607	345.19141918	339.08269048
##	[865]	333.22810811	327.01618789	320.51157523	314.96514688
##	[869]	311.06238113	306.95794842	303.52058397	299.39704205
##	[873]	293.66473391	288.37337738	284.22849036	280.84464792
##	[877]	277.11544173	273.58705414	271.27597803	268.99832329
##	[881]	266.17587185	262.54106522	258.27149391	254.53575229
##	[885]	252.75783687	250.79968799	250.94459046	252.24613679
##	[889]	255.03716337	258.28335878	260.45420357	262.44068767
##	[893]	265.46471255	268.25914278	269.23246316	269.98405892

##	[897]	271.46693953	272.26837491	272.15869808	272.07401958
##	[901]	272.73324922	274.07390214	276.72536460	277.57041848
##	[905]	275.44678701	271.75226780	268.32747052	266.18554768
##	[909]	264.99395372	261.87927695	258.66418696	255.80728034
##	[913]	252.56188330	249.14485817	245.91081380	243.62845617
##	[917]	240.62006684	239.67872889	239.19306910	238.90205368
##	[921]	238.40351807	239.63870192	239.29394830	236.72703013
##	[925]	235.59787891	234.04181147	233.31141820	231.57873565
##	[929]	230.73681481	229.99126809	229.09189697	228.44121353
##	[933]	227.45850778	226.99907640	228.36959823	229.03860461
##	[937]	229.78936350	231.05707569	232.46834559	234.83229286
##	[941]	236.32737723	237.83903760	239.34670649	239.53188992
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##	[949]	236.34361022	237.51345650	238.92245546	240.41850455
##	[953]	240.49134279	239.27337931	237.43269756	234.84053730
##	[957]	232.62666614	230.42008328	228.72634584	227.51345163
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##	[965]	221.93808420	220.05919448	217.30014657	214.69901401
##	[969]	213.97853359	216.31107919	219.09920982	221.69575019
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##	[977]	234.23441639	235.04437912	234.57135404	232.52966922
##	[981]	228.97900210	224.94260132	222.92799923	221.03825961
##	[985]	220.11661787	219.20136223	219.17026513	218.41810183
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##	[993]	224.73267363	227.22720697	228.84955252	230.59620826
##	[997]	231.86475052	233.54309248	237.46574863	242.32284835
##	[1001]	249.26317627	255.83507170	261.31727175	265.41893063
##	[1005]	268.67738923	270.30710930	270.66948136	270.81066416
##	[1009]	271.04474185	270.87371874	270.66011900	269.69803258
##	[1013]	268.49051125	267.67371259	265.68459907	264.56113005
##	[1017]	264.94514053	264.89365871	264.71762822	266.10358674
##	[1021]	270.11780274	272.36759375	273.11806900	274.23669462
##	[1025]	275.00550493	275.58314434	275.92383653	274.97803162
##	[1029]	273.67702543	271.95246131	267.52507708	262.54992078
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##	[1037]	259.57052066	261.90955386	266.13837943	271.84378503
##	[1041]	278.02874349	285.72242680	293.55331517	299.57675946
##	[1045]	303.69038485	306.60114621	307.62123096	309.24152736
##	[1049]	310.97132150	312.69164016	315.18893329	315.42331300
##	[1053]	313.91338523	311.44089011	310.05000969	309.76142720
##	[1057]	311.60431251	311.99012937	311.88152035	311.63674265
##	[1061]	311.45093492	311.05742305	310.99472592	310.87104615
##	[1065]	310.02078648	309.04416356	309.42810505	311.03173865
##	[1069]	312.00000511	311.11502006	310.48861067	308.97044186
##	[1073]	306.80287144	303.46402368	299.73005305	296.04165086
##	[1077]	291.65200569	288.48533480	285.17690186	282.35404695
##	[1081]	281.98683785	284.21043552	287.74912906	291.30251896
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##	[1089]	305.08693360	308.57896789	312.10065225	317.30400599
##	[1093]	323.30089660	328.57967806	332.85223149	336.85355135
##	[1097]	341.23677957	344.44256534	344.62414572	344.24995508
##	[1101]	345.11001429	346.13898116	346.97436334	347.50603343
##	[1105]	348.97893031	350.61383150	352.69116971	356.04536610
##	[1109]	360.37864200	364.58849706	369.19538980	374.27037622

##	[1113]	378.63153569	382.94769802	387.11280362	391.30702217
##	[1117]	395.46248388	399.80749941	403.77657794	407.41058659
##	[1121]	410.39786354	413.24549303	416.56549550	419.64393687
##	[1125]	421.08805085	422.59816390	423.71735958	425.05377949
##	[1129]	428.00408339	431.44047735	435.21473217	440.28173060
##	[1133]	445.72440606	450.41582314	453.15599828	454.93329912
##	[1137]	457.11084117	461.08103633	465.64410447	470.14497958
##	[1141]	474.47996846	479.86011947	486.02357408	491.51714696
##	[1145]	497.92308532	504.45312743	508.87762096	514.24764620
##	[1149]	520.70294605	525.66375323	529.20058989	531.86685509
##	[1153]	533.80517416	536.31297847	538.81509860	541.46079179
##	[1157]	545.31657933	548.46633033	550.46358669	554.34896759
##	[1161]	558.82368583	564.02382363	568.40554996	571.72681001
##	[1165]	575.41435776	578.80549240	581.39239494	583.83500011
##	[1169]	586.12272710	588.35400810	589.57847949	589.73771758
##	[1173]	591.26997529	593.16087548	596.33796918	600.99029821
##	[1177]	604.10010185	607.45891861	610.74615498	613.61896805
##	[1181]	615.26098323	617.41654139	620.96143061	626.64423034
##	[1185]	634.12114623	640.05577830	645.04846207	649.19777281
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##	[1193]	666.83539601	670.19516156	673.32784629	676.96323697
##	[1197]	679.37202390	681.38591808	684.02947717	686.33652904
##	[1201]	688.15439512	690.91428474	693.36948084	696.01442010
##	[1205]	698.53137930	700.73259387	702.11052557	703.90746655
##	[1209]	704.32450549	705.46455019	706.42784821	706.59392566
##	[1213]	706.69691482	707.68972463	709.01387241	711.28042666
##	[1217]	714.05159892	716.66679519	721.24978816	726.13304988
##	[1221]	730.95500962	736.25505601	740.42172714	742.78799522
##	[1225]	743.10433744	742.33583969	742.02745757	743.66564432
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##	[1233]	744.84749473	746.40435400	749.03314428	752.34223160
##	[1237]	755.83443272	759.34210409	761.12094788	761.67319663
##	[1241]	760.98120063	760.46694668	760.43018231	760.29267502
##	[1245]	760.21721751	760.81415244	761.74203581	761.19590268
##	[1249]	760.88641071	759.95924029	757.94090115	756.15262782
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##	[1261]	730.55366075	725.72172801	720.23121038	715.14285944
##	[1265]	710.06346207	706.13859570	703.10467785	700.41430585
##	[1269]	696.02349466	689.93480874	683.22438332	676.95026450
##	[1273]	672.42328752	667.64680047	664.33086967	662.07980716
##	[1277]	658.72150333	656.57533569	654.68144741	653.24366810
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##	[1285]	660.43570356	664.88000639	670.21736905	675.86077596
##	[1289]	679.80891196	683.06365775	686.54991189	689.66405917
##	[1293]	694.52880932	700.16839876	706.35123913	713.36586605
##	[1297]	718.70880185	724.11123038	730.76347411	738.53763960
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##	[1309]	771.23105736	773.38892083	774.37879419	775.42306556
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##	[1317]	776.89320170	777.40321403	778.71851540	779.91960092
##	[1321]	780.53081649	778.94138263	776.95910766	776.32954097
##	[1325]	775.48571243	774.93744625	775.17952002	775.86211628

##	[1329]	775.46164237	775.29765652	776.82580132	777.02100077
##	[1333]	776.35672283	775.63842007	773.76931895	772.44069610
##	[1337]	773.59691182	774.71539313	773.81394573	771.85580396
##	[1341]	767.82586102	763.26733711	759.44049817	757.48097848
##	[1345]	754.28354136	750.79989178	747.64554896	744.75365232
##	[1349]	740.94224614	738.20992483	735.49723800	732.76913802
##	[1353]	730.32989515	728.57571590	725.43799812	722.36949227
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##	[1365]	684.21534427	681.33826905	677.81173936	674.96194667
##	[1369]	671.37697773	667.10416077	663.20278651	659.57295369
##	[1373]	656.15009683	653.80686364	651.67751191	649.96614042
##	[1377]	649.83123589	649.59547536	648.69274730	648.09739124
##	[1381]	647.24737312	644.23737700	639.63924399	635.88511086
##	[1385]	633.45128340	631.36856352	630.17145357	629.65052962
##	[1389]	629.12454103	625.49464464	620.70376020	615.85579899
##	[1393]	612.84344349	611.63503167	610.19500600	608.32939605
##	[1397]	607.34088557	604.91849489	601.47616491	597.36224472
##	[1401]	593.90121334	591.23765979	589.17890782	587.07842629
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##	[7097]	717.18774287	715.92412396	715.34449374	713.58601919
##	[7101]	711.60150618	709.71410423	707.49869601	706.30993857
##	[7105]	704.73352623	701.67337026	698.05733250	695.98079426
##	[7109]	695.86199238	696.90864081	696.65501583	694.96520131
##	[7113]	693.16046830	693.12313715	694.06634024	696.92102303
##	[7117]	699.99348106	701.36083981	702.04886927	703.56057778
##	[7121]	705.44533417	706.78719887	708.50636726	710.00228371
##	[7125]	713.26589641	717.65708207	719.88049027	721.94923769
##	[7129]	723.90668196	725.81056029	728.96484009	730.67784358
##	[7133]	732.11798046	734.66944211	737.76216216	740.03009956
##	[7137]	740.65547399	741.46293622	743.20846343	744.25437182
##	[7141]	746.16456189	748.93426865	752.39536881	755.24992615
##	[7145]	758.05830281	761.71470720	766.58085658	770.62470111
##	[7149]	772.46522736	774.27924051	776.03192216	777.53432783
##	[7153]	780.13997441	782.70599646	785.99562256	788.83759901
##	[7157]	790.30290812	791.31859974	792.26105989	793.09303053

##	[7161]	793.20109336	792.40077987	789.89187575	786.30470598
##	[7165]	783.28142317	779.81638358	777.75431328	775.60670008
##	[7169]	773.05008112	771.74470513	770.01634462	767.81485622
##	[7173]	767.08401683	766.66555145	766.46699371	766.92498755
##	[7177]	767.13550934	767.60130101	766.03785995	764.11653911
##	[7181]	761.76911852	759.23679260	756.92847603	754.71563962
##	[7185]	754.27192411	755.04147224	754.72726343	753.67139213
##	[7189]	751.57487046	749.39861829	746.44331667	742.00742105
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##	[7197]	713.31560289	710.11139149	706.76561294	703.22136001
##	[7201]	701.15767580	700.70057270	698.18036089	696.25756650
##	[7205]	697.09301402	696.92128284	696.50884328	696.04131555
##	[7209]	695.85394495	694.56190611	692.85333887	690.42927228
##	[7213]	689.52711196	688.03033691	683.59872624	678.32346332
##	[7217]	672.29539878	667.54388388	663.99529591	659.46645034
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##	[7229]	643.60142299	643.24422425	643.46989004	643.03367755
##	[7233]	641.38516769	638.99523050	634.46005029	629.34588441
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##	[7241]	610.52569214	609.67712933	609.53910590	607.76307189
##	[7245]	606.85158042	605.38601215	603.05313482	600.36689465
##	[7249]	599.98828178	601.25302738	603.34528531	605.62202306
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##	[7269]	645.43147415	646.43736919	646.66540471	644.46889168
##	[7273]	644.12097349	646.01767655	647.37091228	648.18483618
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##	[7281]	638.96394190	638.97897601	639.07347955	638.99796222
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##	[7293]	625.39835302	621.41930390	617.26501760	612.37197180
##	[7297]	607.72248184	601.93920757	596.45799572	590.85215632
##	[7301]	586.62938591	581.27547019	575.14249532	569.70070179
##	[7305]	564.95633412	562.38808828	560.56034062	557.81688003
##	[7309]	554.38691562	550.58705996	547.45315099	544.49217136
##	[7313]	540.09391247	536.05312078	533.54675233	532.84757468
##	[7317]	533.82130164	534.11170015	534.70498021	535.58427843
##	[7321]	535.45046807	536.41817516	536.66384901	536.30826904
##	[7325]	536.03838928	534.33649998	531.63329048	528.94144523
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##	[7333]	505.49248509	501.12517105	497.36304895	495.26069243
##	[7337]	494.47549193	495.29161041	497.47820800	500.65546002
##	[7341]	505.65767377	509.37545930	512.45999285	516.48944392
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##	[7349]	520.23610962	520.55180938	521.35989083	524.20416274
##	[7353]	527.36591223	530.59916282	533.17106384	535.90603209
##	[7357]	540.02867825	543.92948082	548.47758910	553.76430413
##	[7361]	560.06150565	565.66004570	571.09389399	575.93867947
##	[7365]	581.34542079	585.92835847	590.75380362	596.21571144
##	[7369]	600.68634119	604.14501249	607.30639886	610.26534839
##	[7373]	612.06355995	612.15580157	611.39580114	611.67756261

##	[7377]	612.91439384	613.77471227	614.36290244	617.99178809
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##	[7385]	632.26557516	632.37028147	630.12567461	625.40531766
##	[7389]	620.26483961	617.31660717	615.63665533	612.33347128
##	[7393]	609.35531131	606.08582375	602.91242602	600.96203611
##	[7397]	598.92930133	596.88963503	597.20071264	597.78377122
##	[7401]	598.18322229	600.09890501	602.24661433	604.36387775
##	[7405]	606.50799863	609.71843814	616.49917096	624.77668566
##	[7409]	630.44444886	635.11848921	640.40307158	646.41432326
##	[7413]	651.24343155	656.79248678	660.68609983	663.90746410
##	[7417]	667.87329024	671.88088045	674.66185942	678.27487037
##	[7421]	682.10142773	684.13580639	683.90678911	683.42041305
##	[7425]	682.73975403	681.56866518	680.12739635	677.78141556
##	[7429]	674.83406850	672.54845593	670.57976289	667.24323775
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##	[7441]	620.02052116	619.21013530	619.59056647	619.87890601
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##	[7461]	606.51095199	603.29685830	600.65692049	598.02926212
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##	[7481]	643.00299354	648.10227345	653.58913835	656.73556253
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##	[7501]	609.28118014	606.01752016	604.07933873	602.74073207
##	[7505]	601.00073554	600.09294818	599.03842918	596.44904700
##	[7509]	594.06168281	590.42268688	586.06303782	581.01174413
##	[7513]	575.48432923	568.88899731	562.18096784	557.12413791
##	[7517]	551.55718307	544.47963275	537.09239976	530.82634711
##	[7521]	525.33160574	521.43123625	519.87471007	517.89229579
##	[7525]	513.89983610	508.91450340	501.91337638	494.36169683
##	[7529]	485.59522803	477.46155302	469.27409704	461.83797604
##	[7533]	456.85487964	453.32334474	450.23753913	446.94343781
##	[7537]	445.12966660	444.48310689	442.66637089	442.42934425
##	[7541]	443.76757160	444.56412501	444.07244947	444.02349718
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##	[7549]	450.97000950	451.39858270	450.95953210	450.06316634
##	[7553]	448.76439032	446.45127240	444.03391448	441.27183988
##	[7557]	440.00212862	441.87781716	443.88674322	445.17717718
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##	[7569]	467.63563320	465.92631763	464.98205385	466.30672102
##	[7573]	467.90242221	469.74405241	471.24216594	473.69400685
##	[7577]	476.04796308	480.49189097	485.75367018	490.68084721
##	[7581]	495.11225786	498.57426850	503.39851329	508.63078751
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##	[7593]	548.14726555	552.08420373	555.23210919	558.54506464
##	[7597]	561.48118804	564.82926651	567.89574780	570.45349379
##	[7601]	572.21668949	573.52393868	575.14962372	577.31565966
##	[7605]	579.59969567	580.61921424	581.96720599	583.73112955
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##	[7613]	585.23841769	587.13969307	590.74495718	596.45249403
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##	[7633]	660.84934296	666.23536629	671.08132504	674.67570624
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##	[7653]	635.09217138	634.31402397	634.24533502	633.27142207
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##	[7685]	559.46282237	556.33543439	551.80705923	545.19141017
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##	[7705]	479.46359906	477.61660959	475.25599373	471.62210043
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##	[7841]	294.20880869	289.63637994	287.82580722	285.37587722
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##	[7921]	139.52212339	139.02845847	137.57089900	135.97179491
##	[7925]	134.97210649	134.18160956	133.40861163	131.80035477
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##	[7953]	91.71972065	89.63794035	87.10402122	84.89255305
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##	[7961]	79.88932817	80.43967635	82.29828719	83.63473307
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##	[7977]	79.36337330	77.99763664	76.15325072	74.71964013
##	[7981]	71.98304857	69.52729673	67.90422901	64.88217215
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##	[7993]	38.84746688	31.54494107	26.18822145	21.49980936
##	[7997]	16.14898672	10.96287184	5.88888062	0.80838743
##	[8001]	-5.76432389	-11.90804716	-16.76603139	-19.13649580
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##	[8017]	-6.11261898	-4.24835693	-3.21182850	-1.39731961
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##	[8981]	313.52728679	314.28743946	315.12055228	313.74201556
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##	[8997]	311.51239753	312.06167127	312.93158130	314.61290156
##	[9001]	316.28258983	317.90149902	318.81459697	320.83159270
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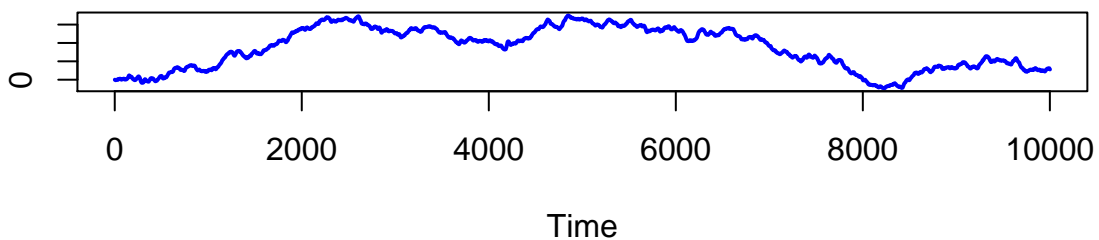
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##	[9921]	252.35385244	251.84127710	249.38363312	246.02799882
##	[9925]	243.91526687	242.53686284	242.11157967	241.52676405
##	[9929]	240.87169285	240.42183831	240.68277668	240.82265289
##	[9933]	241.51041671	242.05647590	242.10736859	241.80678728
##	[9937]	241.54945246	243.84226757	244.61536635	242.49300906
##	[9941]	239.16734608	235.54964274	232.72251623	228.43677334
##	[9945]	224.44259156	222.90021437	223.48200396	224.62916641
##	[9949]	226.38702709	229.76442966	233.68872781	236.96832173
##	[9953]	240.49722731	244.39685651	248.51324311	252.53205265
##	[9957]	255.77635303	259.29163565	263.00589847	266.67603274
##	[9961]	270.44405945	272.94043808	276.22355486	279.99474872
##	[9965]	282.97656647	285.88988011	288.20233909	291.29535465

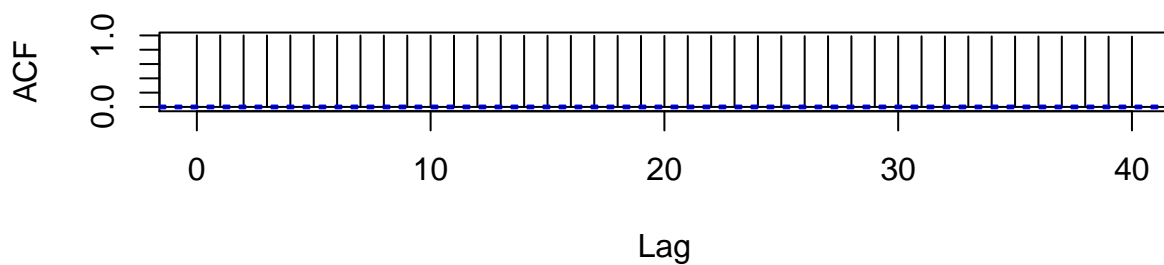

```
## [9969] 293.65637207 295.32209378 297.23365407 299.42205587
## [9973] 299.98276341 300.31406488 300.38294125 300.61365630
## [9977] 301.18794753 302.58672016 302.87819642 302.46338899
## [9981] 301.57428038 301.78556775 302.90944540 305.15419247
## [9985] 305.74478091 306.50409566 307.49801909 308.73942154
## [9989] 310.59596086 312.51036067 313.10944202 313.65663453
## [9993] 312.57643866 308.94432825 303.81473179 298.80223686
## [9997] 294.76884410 291.26182243 287.32071697 283.22411975
## [10001] 279.92970130
```

```
par(mfrow=c(2,1))
plot(Simulated.Arima,ylab=' ',
     main='Simulated time series from ARIMA(2,1,1)',col='blue',lwd=2)
#systematic change in trend-not stationary
acf(Simulated.Arima)
```

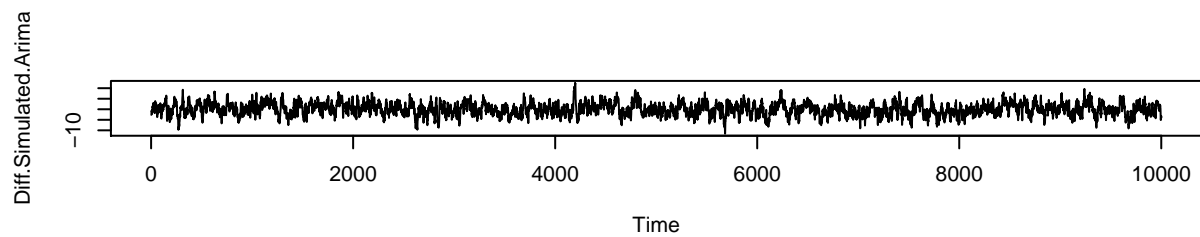
Simulated time series from ARIMA(2,1,1)



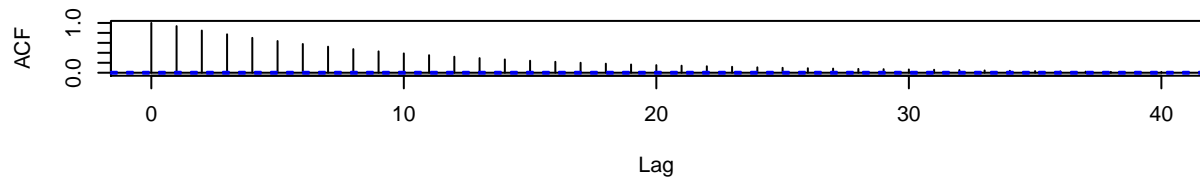
Series Simulated.Arima



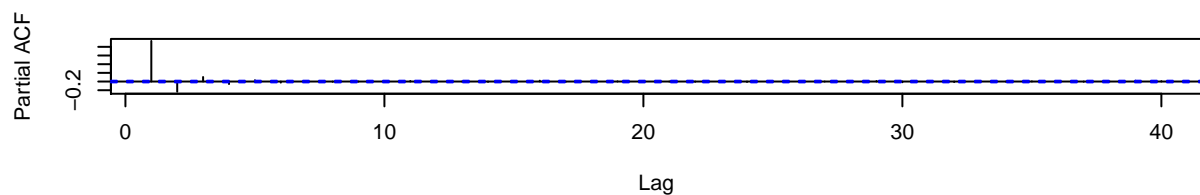
```
#difference operator
Diff.Simulated.Arima=diff(Simulated.Arima)
par(mfrow=c(3,1))
plot(Diff.Simulated.Arima) #no systematic change in trend-stationary
acf(Diff.Simulated.Arima)
pacf(Diff.Simulated.Arima)
```



Series Diff.Simulated.Arima



Series Diff.Simulated.Arima



```
library(forecast)
auto.arima(Simulated.Arima)
```

```
## Series: Simulated.Arima
## ARIMA(4,2,0)
##
## Coefficients:
##          ar1      ar2      ar3      ar4
##          0.2279 -0.1633  0.0337 -0.0707
## s.e.    0.0100  0.0102  0.0102  0.0100
##
## sigma^2 estimated as 1.064:  log likelihood=-14495.62
## AIC=29001.24  AICc=29001.25  BIC=29037.29
```

```
fit1=arima(Diff.Simulated.Arima,order = c(4,0,0))
fit1
```

```
##
## Call:
## arima(x = Diff.Simulated.Arima, order = c(4, 0, 0))
##
## Coefficients:
##          ar1      ar2      ar3      ar4  intercept
##          1.1862 -0.3761  0.1733 -0.0581   0.0280
## s.e.    0.0100  0.0154  0.0154  0.0100   0.1353
```

```
##
## sigma^2 estimated as 1.025: log likelihood = -14313.1, aic = 28638.2

fit2=arima(Diff.Simulated.Arima,order = c(2,0,1))
fit2

##
## Call:
## arima(x = Diff.Simulated.Arima, order = c(2, 0, 1))
##
## Coefficients:
##          ar1      ar2      ma1  intercept
##          0.6876  0.204  0.5002      0.0280
## s.e.      0.0334  0.032  0.0301      0.1398
##
## sigma^2 estimated as 1.023: log likelihood = -14305.92, aic = 28621.83

fit3=arima(Diff.Simulated.Arima,order = c(2,1,1))
fit3

##
## Call:
## arima(x = Diff.Simulated.Arima, order = c(2, 1, 1))
##
## Coefficients:
##          ar1      ar2      ma1
##          -0.1502 -0.0690  0.3818
## s.e.      0.0766  0.0218  0.0768
##
## sigma^2 estimated as 1.068: log likelihood = -14515.33, aic = 29038.65

library(astsa)

##
## Attaching package: 'astsa'

## The following object is masked from 'package:forecast':
##
##      gas

#read data to R variable
#-import csv file from localhost
library(readr)
birth.data<-read_csv("Downloads/daily-total-female-births-in-cal.csv")

## Parsed with column specification:
## cols(
##   Date = col_date(format = ""),
##   `Daily total female births in California, 1959` = col_double()
## )
```

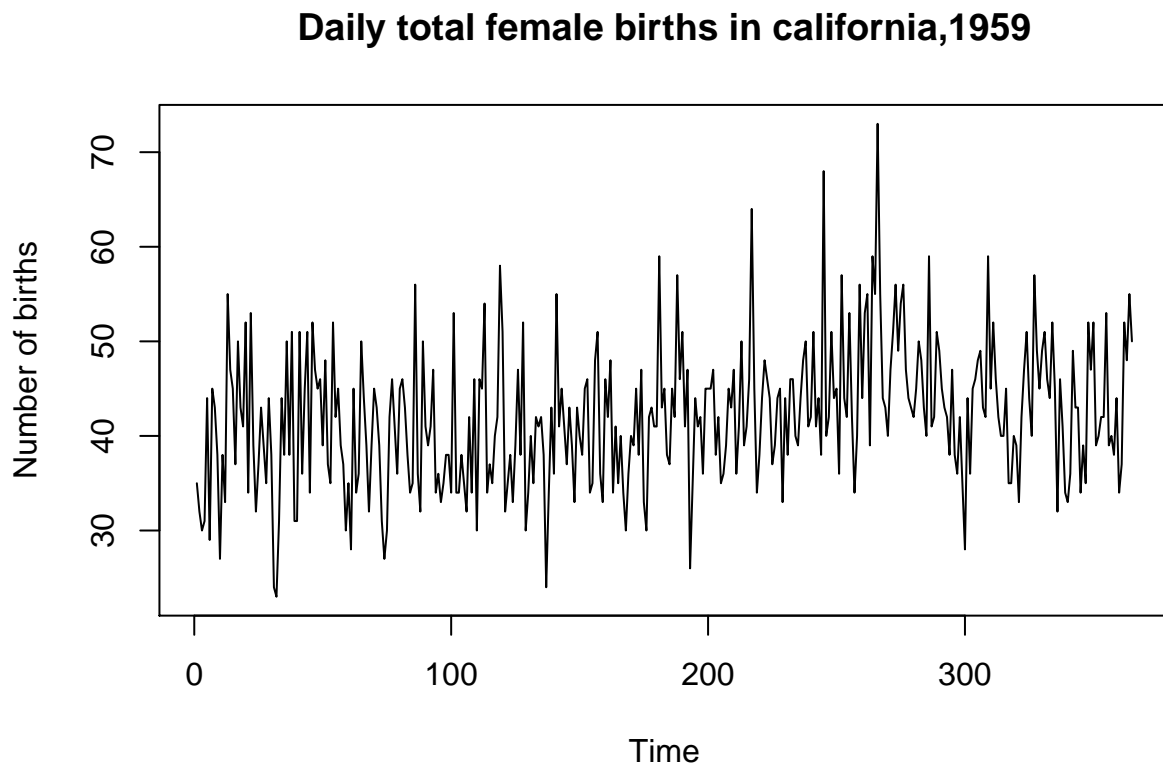
```

#pull out numberof births column
number_of_birth<-birth.data$`Daily total female births in California, 1959`

#use date format for dates
birth.data$Date<-as.Date(birth.data$Date, '%m/%d/%y')

#plot
plot.ts(number_of_birth,
        main='Daily total female births in california,1959', ylab='Number of births')

```



```

# systematic change in trend-not stationary-difference operator
# variation in variance-transformation-log-return

```

```

#Test for correlation
Box.test(number_of_birth,lag = log(length(number_of_birth)))

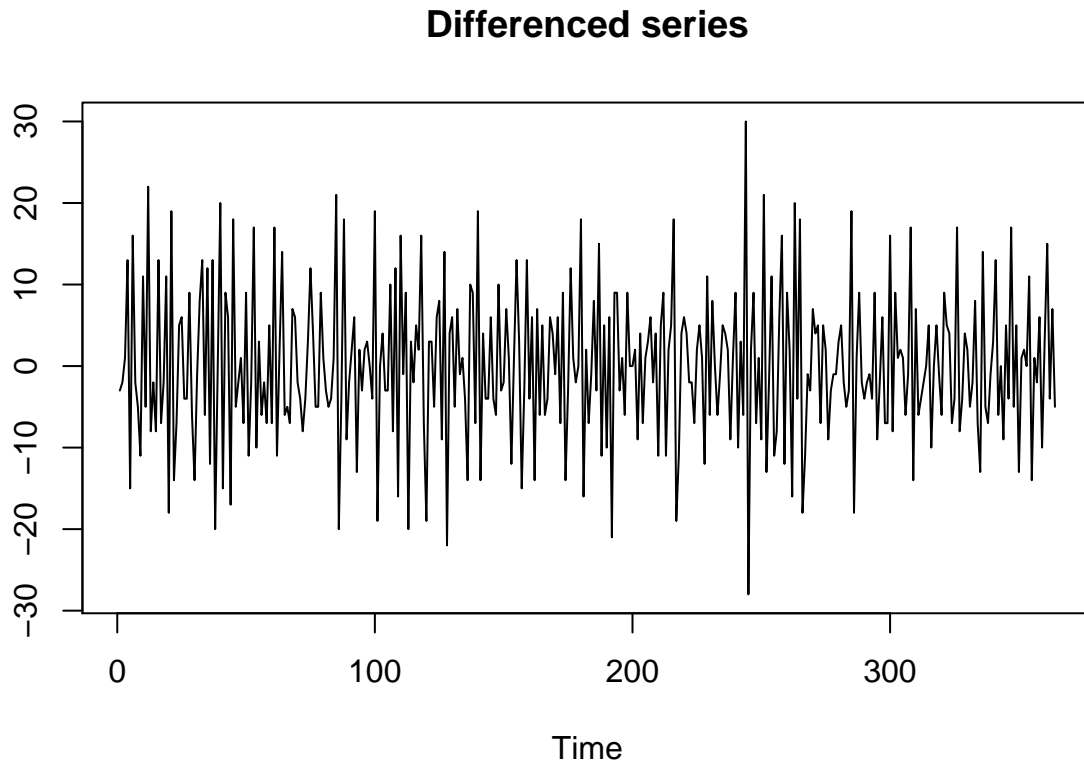
```

```

##
## Box-Pierce test
##
## data:  number_of_birth
## X-squared = 36.391, df = 5.8999, p-value = 2.088e-06

```

```
#differenced data-plot
plot.ts(diff(number_of_birth),main='Differenced series',ylab='')
```

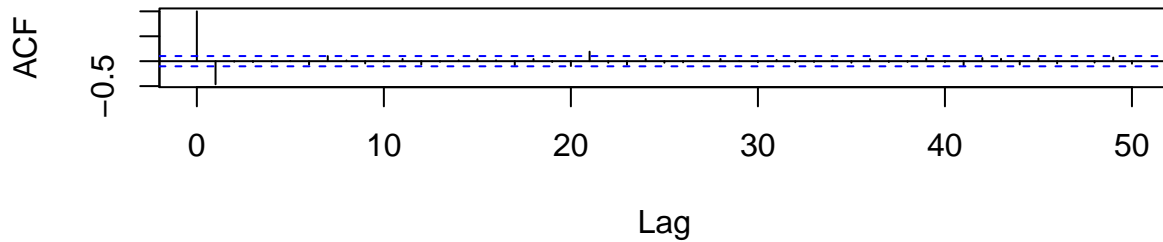


```
#Test for correlation in the differenced data
Box.test(diff(number_of_birth),lag = log(length(diff(number_of_birth))))
```

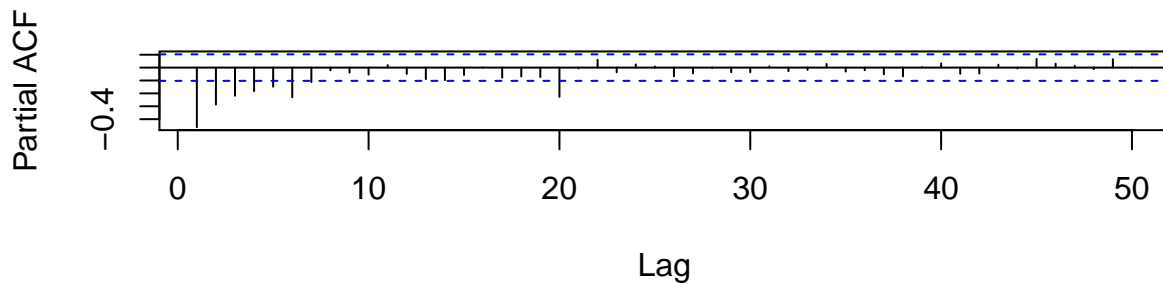
```
##
## Box-Pierce test
##
## data: diff(number_of_birth)
## X-squared = 78.094, df = 5.8972, p-value = 7.661e-15
```

```
# ACF and PACF of the differenced data
par(mfrow=c(2,1))
acf(diff(number_of_birth),main='ACF of differenced data',50) #1 spike
pacf(diff(number_of_birth),main='PACF of differenced data',50) #7 spikes
```

ACF of differenced data



PACF of differenced data



```
auto.arima(number_of_birth)
```

```
## Series: number_of_birth
## ARIMA(0,1,2)
##
## Coefficients:
##          ma1      ma2
##      -0.8478 -0.1079
## s.e.   0.0497  0.0496
##
## sigma^2 estimated as 49.49:  log likelihood=-1226.79
## AIC=2459.57   AICc=2459.64   BIC=2471.26
```

```
# Fit various ARIMA models
model1=arima(number_of_birth,order = c(0,1,1))
SSE1=sum((model1$residuals)^2)
model1.test=Box.test(model1$residuals,lag = log(length(model1$residuals)))

model2=arima(number_of_birth,order = c(0,1,2))
SSE2=sum(model2$residuals^2)
model2.test=Box.test(model2$residuals,lag = log(length(model2$residuals)))

model3=arima(number_of_birth,order = c(7,1,1))
SSE3=sum((model3$residuals)^2)
model3.test=Box.test(model3$residuals,lag = log(length(model3$residuals)))
```

```

model4=arima(number_of_birth,order = c(7,1,2))
SSE4=sum((model4$residuals)^2)
model4.test=Box.test(model4$residuals,lag = log(length(model4$residuals)))

df=data.frame(row.names = c('AIC','SSE','p-value'),
              c(model1$aic,SSE1,model1.test$p.value),
              c(model2$aic,SSE2,model2.test$p.value),
              c(model3$aic,SSE3,model3.test$p.value),
              c(model4$aic,SSE4,model4.test$p.value))
colnames(df)=c('ARIMA(0,1,1)',
               'ARIMA(0,1,2)',
               'ARIMA(7,0,1)',
               'ARIMA(7,0,2)')
format(df, scientific = FALSE)

```

```

##          ARIMA(0,1,1)  ARIMA(0,1,2)  ARIMA(7,0,1)  ARIMA(7,0,2)
## AIC      2462.2207021  2459.5705306  2464.8827225  2466.6664136
## SSE      18148.4561632 17914.6513437 17584.3902548 17574.0578105
## p-value   0.5333604    0.9859227    0.9999899    0.9999929

```

```

d=2
for(p in 1:4){
  for(q in 1:2){
    if(p+d+q<=6){
      model<-arima(x=BJsales, order = c((p-1),d,(q-1)))
      pval<-Box.test(model$residuals, lag=log(length(model$residuals)))
      sse<-sum(model$residuals^2)
      cat(p-1,d,q-1, 'AIC=', model$aic, ' SSE=',sse,' p-VALUE=', pval$p.value,'\n')
    }
  }
}

```

```

## 0 2 0 AIC= 577.6777  SSE= 423.7908  p-VALUE= 7.610494e-07
## 0 2 1 AIC= 517.1371  SSE= 276.2293  p-VALUE= 0.9632467
## 1 2 0 AIC= 541.9646  SSE= 327.92   p-VALUE= 0.003606979
## 1 2 1 AIC= 518.9734  SSE= 275.8554  p-VALUE= 0.941776
## 2 2 0 AIC= 532.2986  SSE= 302.7467  p-VALUE= 0.05824473

```