Understanding ETAS

(bit.ly/quakers_etas)

Epidemic-Type Aftershock Sequence

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0 Assumptions the ETAS model is based on:

1. The background seismicity follows the Poisson process.
2. The number of the aftershocks are exponentially proportional to the magnitude of the earthquake.
3. Decrease of aftershocks follows modified Omori law.

1 Quick review of point process

A **point-process** is just a random process that tracks the number of times an event occurs in some time interval.

Conditional intensity is how many events we can expect in the next period of time, given the history.

$$\lambda(t|H_t) = \lim_{\Delta t \to 0} \frac{1}{\Delta t} P(\text{One event occurs in the time-interval}\,[t, t+\Delta t] \mid H_t),$$

1 According to Prof. Stark's lecture,

Overall conditional intensity at time t given the history:

[redacted] # of direct
[redacted] of an
[redacted] sized m_i

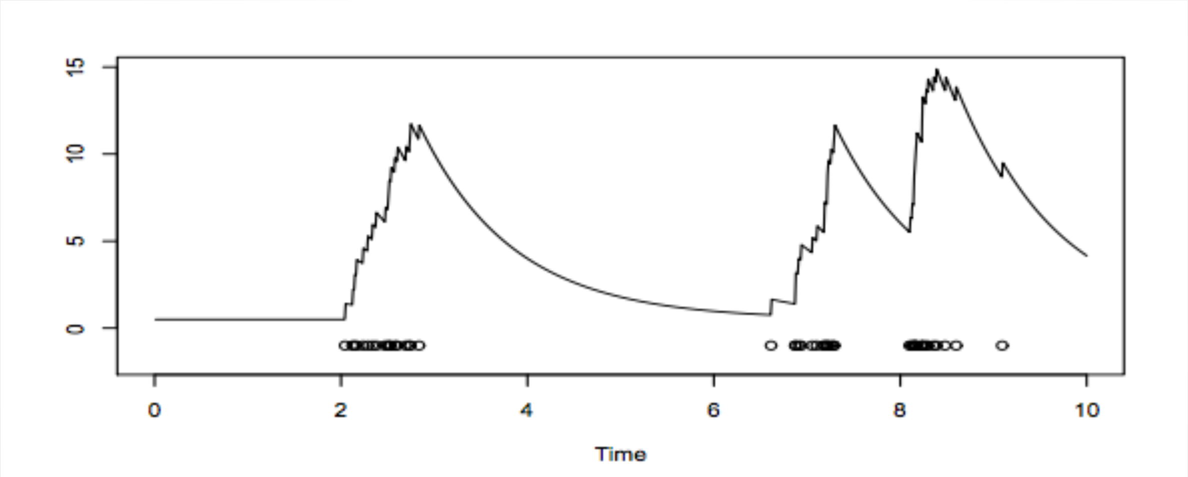
[redacted]

of events with $M \geq m_0$

Heuristically, K is a function of magnitude and the others are tuning parameters

[redacted]

1 Example of an ETAS Process



2 ETAS Library in R

By fitting to the data, the ETAS model determines the parameters by the maximum likelihood method. Thus we can predict the incidence of the earthquake, conforming to regional diversity.

---> ETAS package in R returns the MLE of the parameters of the model (μ, K, c, α, p); in addition to these, the R ETAS function also returns D, q, and gamma.

2 More specifically…

etas() returns:

--param: the MLE of the model parameters;

--bk: estimates of u(x,y), the bckground intensity; (exact formula can be found in the etas package library)

--pb: probabilities of being background event, i.e., the mainshock;

--opt: results of optimization-the value of the log-likelihood function at the optimum point, its gradient at optimum point, and AIC (a measure of the relative quality of a statistical model, for a given set of data; provides a means for model selection) of the model;

--rates: pixel images of the estimated total intensity, background intensity, clustering intensity, and conditional intensity;

If you input a dataset like this...

	time	long	lat	mag	mag.type	depth	ref	date
1	43.40215	48.71	40.72	6.0	mb	33	BER77	1902/02/13 09:39:06
2	45.11111	48.60	40.70	5.0	M	15	MOS	1902/02/15 02:40:00
3	46.75764	47.40	40.20	5.2	M	32	MOS	1902/02/16 18:11:00
4	51.00000	48.80	41.80	5.6	Ms	36	ULM	1902/02/21 00:00:00
5	57.00347	48.00	40.50	4.6	M	18	MOS	1902/02/27 00:05:00
6	247.18958	48.00	39.50	4.8	Ms	20	MEA	1902/09/05 04:33:00
7	275.96181	45.60	41.90	5.2	Ms	33	KAR	1902/10/03 23:05:00
8	276.07361	45.60	41.90	4.9	Ms	33	KAR	1902/10/04 01:46:00
9	289.30625	45.90	41.90	5.2	Ms	33	KAR	1902/10/17 07:21:00
10	298.48403	47.80	39.70	4.7	Ms	14	MEA	1902/10/26 11:37:00

...Then the function will return this:

```
ETAS model: fitted using iterative stochastic declustering method
ML estimates of model parameters:
         mu           A           c       alpha           p           D           q 
0.433967794 0.198862790 0.034520601 1.629013688 1.128677604 0.007253937 2.170588305 
      gamma 
0.570640224 
log-likelihood:  -14627.34 
AIC:  29270.68
```

2 With the estimated parameters, we can:

-- **calculate the conditional intensity** at any point in time

-- **turn on an alarm** whenever the conditional intensity is above some threshold

-- then **simulate future seismicity** from the process; and determine τ and v

2 Then..

Finding τ and ν for a continuum of thresholds gives an error diagram, commonly used to examine predictive success.