Elliptic curves cryptography

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- What do we need to construct the group ?
- How to construct the group ?
- What are its application in cryptography ?
- Why does it work ?
- What are the cons and pros ?

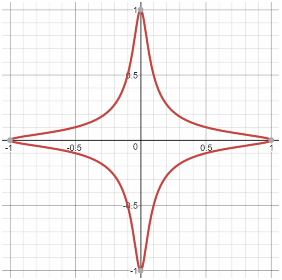
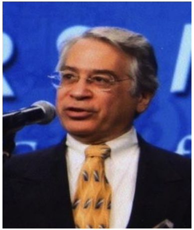


Figure 1: Edwards' Curve : $x^2 + y^2 = 1 + 300x^2y^2$

Research papers

- Neal Koblitz, *Elliptic curve cryptosystems*, 1985 [4]
- Victor S. Miller, *Use of elliptic curve in cryptography*, 1985 [6]

Neal Koblitz



Victor Saul Miller

The tools to build $(E, +)$

- Projective plane
- Projective lines
- Straight and tangent lines
- Rational points

Projective plane

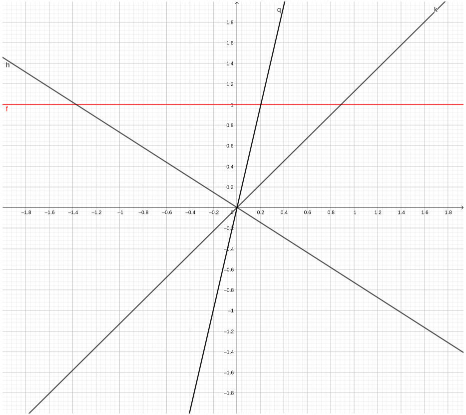


Figure 2: Projective line in red

Affine slice of the projective plan and the infinity point

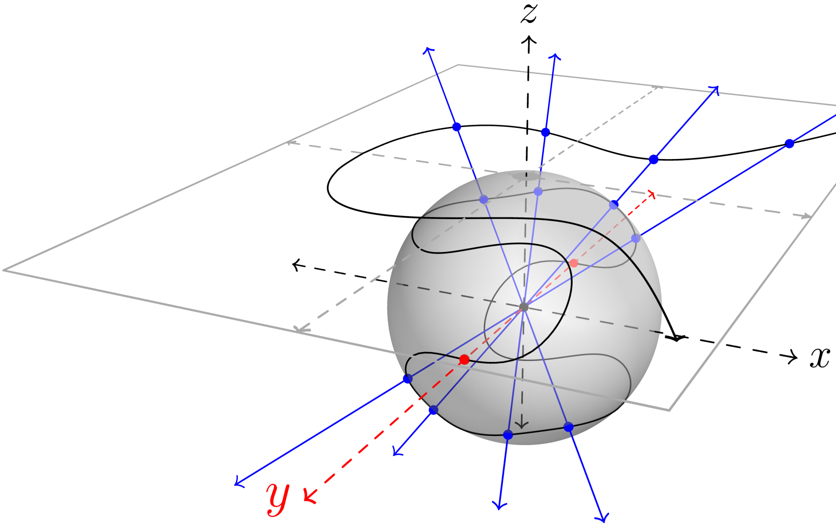


Figure 3: Elliptic curve of equation $y^2 = x^3 - x + 1$ on the projective plane

Definition

An elliptic curve define over a field K is a projective plane curve where its homogeneous equation is

$$y^2z = x^3 + axz^2 + bz^3, \qquad (1)$$

where a and b are elements of K which verify the following condition

$$\Delta = -(4a^3 + 27b^2) \neq 0. \qquad (2)$$

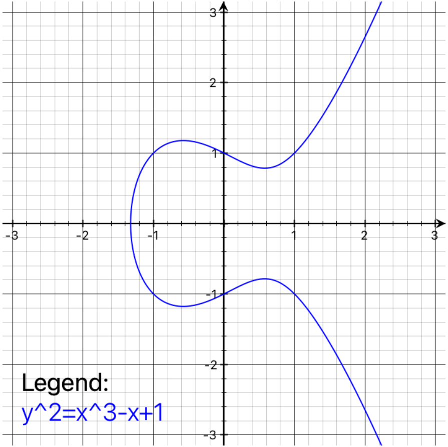


Figure 4: canonical curve with $\Delta < 0$

- **Weierstrass normal equation**

$$y^2 = x^3 + ax + b,$$

- **Rational points set**

$$E(K) = \{P \in \mathbb{P}_2 \mid y^2 = x^3 + ax + b\} \cup \{\mathcal{O}\}$$

- **Infinity point**

$$\mathcal{O} = [0, 1, 0].$$

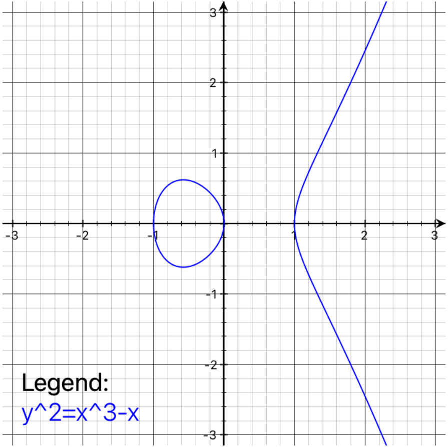


Figure 5: canonical curve with $\Delta > 0$

Non associative binary operation

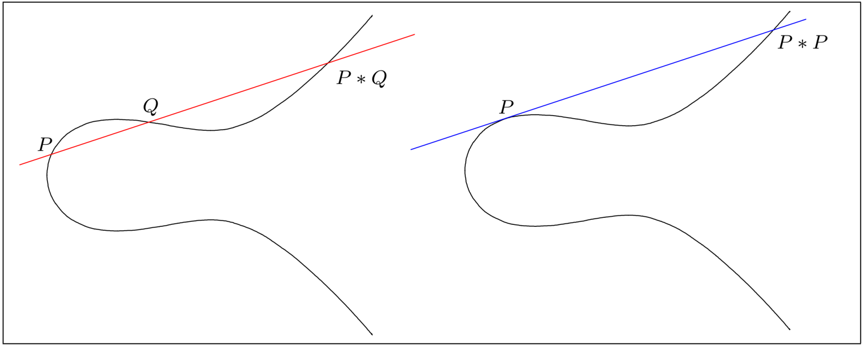


Figure 6: binary operation of chord and tangent of the curve

Abelian group

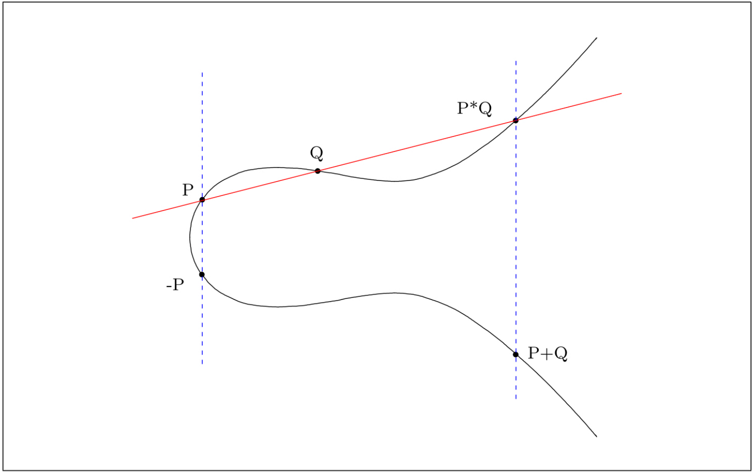


Figure 7: Geometric representation of the addition of rational points

Discrete logarithm

The problem of discrete logarithm

Let E be an elliptic curve define over a field K.
Let $Q \in E(K)$ be a rational point.
Given a rational point $P \in E(K)$, the discrete logarithm problem is to find $n \in \mathbb{N}$, if its exists, such as $P = nQ$.

Why it works:

- One-way functions exist.
- Unsolvability of the discrete logarithm problem.
- No other way to solve the Diffie-Hellman's problem.

Public key-sharing protocol

Diffie-Hellman protocol

Alice and Bob would like to share a secret key (i.e. know only by themselves) over a non-secure channel.
To do this they proceed the following way:

1) They choose and publish the triplet (K, E, P).
2) Alice chooses $a > 0$ and computes $P_a = aP$, which she sends to Bob.
3) Bob chooses $b > 0$ and computes $P_b = bP$, which he sends to Alice.
4) Alice and Bob compute aP_b and bP_a which gives P_{ab}.

Conclusion: pros and cons

Pros

- Abstract structure.
- Shorter secret key length.
- Low ressources usage.
- Hybrid cryptosystem compatibility.

Cons

- Many are patented
- Build-in trap doors? [3] [2]

The following is a statement of Serge Lang in his book
Elliptic curve: Diophantine analysis, 1978 [5]:

"It is possible to write endlessly on elliptic curves. (This is not a threat)"

Thank you for your attentention.

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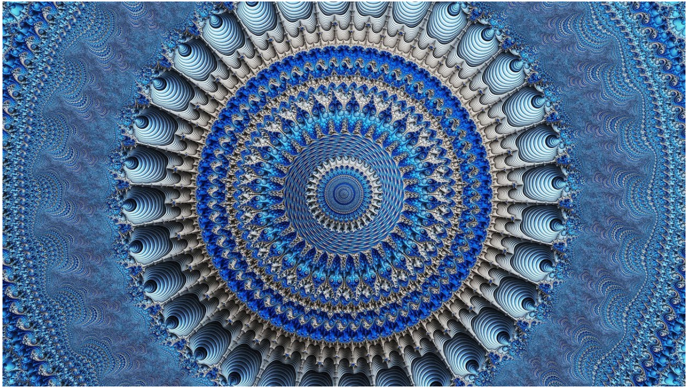

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References

Pictures sources:

- Trustica.cz [7].
- Stackexchange forum [9].
- allaboutcircuits.com [1]
- Alchetron.com [8]

[1] *Dr. Neal Koblitz: Independent Co-creator of Elliptic Curve Cryptography - News*. url: https://www.allaboutcircuits.com/news/dr.-neal-koblitz-independent-co-creator-of-elliptic-curve-cryptography/ (visited on 06/20/2022).

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