MPHELL library

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Introduction

MPHELL

- C multi-precision high performance library for the arithmetic of (hyper-)elliptic curves used in cryptography.
- Different coordinates systems are used and other libraries can be plugged into MPHELL (like PARI).
- Current development only concerns elliptic curves.
- Industrial perspectives.
- Release is expected for q1 of 2016.

Different families of elliptic curves

We work with prime fields $\mathbb{F}_p$, $p \neq 2, 3$.

Curves supported

- Weiertstrass curves (projective and jacobian coordinates)

$$E_{a,b} : y^2 = x^3 + ax + b, a, b \in \mathbb{F}_p, 4a^3 + 27b^2 \neq 0$$

- Jacobi Quartic curves (extended projective coordinates)

$$JQ_a : y^2 = z^2 + 2ax^2 + t^2, x^2 = zt, a \in \mathbb{F}_p, a \neq 1.$$

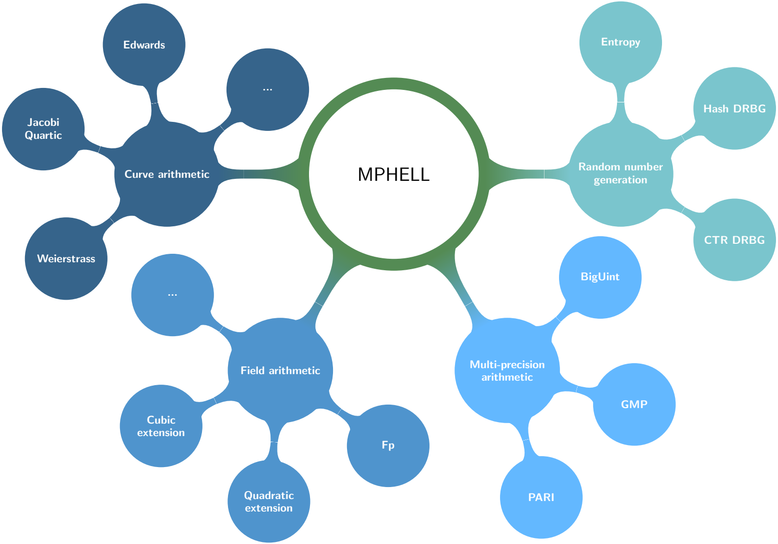
- Twisted Edwards curves (extended projective coordinates)

$$Ed_{a,d} : ax^2 + y^2 = dt^2 + z^2, xy = zt, a, d \in \mathbb{F}_p, ad(a - d) \neq 0.$$

Computation costs for prime curves

Coordinates system	Doubling	General addition
Affine	1I,2M,2S	1I,2M,1S
Projective	7M,3S	12M,2S
Jacobian	4M,4S	12M,4S
Edwards	3M,4S	9M,1S,1D
Jacobi Quartic	2M,5S,1D	7M,3S,1D

Overall architecture



Functionalities (1)

Random number generation

- DRBG mechanisms as specified in SP800 90-A.
- Possibility to use others generators (including hardware generators)

Multi-precision arithmetic

- Multi-precision integers are represented as table of block.
- The base type used is `uint64_t` but the library can be configured with another block size like `uint32_t`.
- Some functions are implemented in assembly language (only supported for x86-64 architecture).
- Implementation on ARM V7 architecture is in progress.

Functionalities (2)

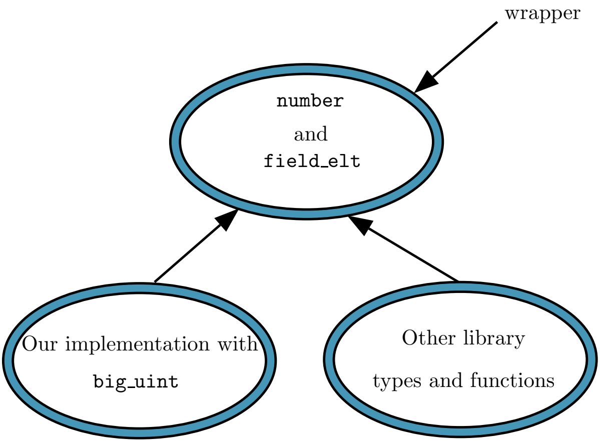
Field arithmetic

- Montgomery representation is used to implement modular function.
- Quadratic and cubic extensions of prime field are available.

Curve arithmetic

- Support for Weierstrass (projective and jacobian coordinates), Jacobi Quartic and Edwards curves (extended projective coordinates).
- Addition (+ CO-Z addition for Weierstrass curves), Doubling, different versions of scalar multiplication (Left-to-Right, Windowed,...)

Plug others libraries



Interaction with PARI

- big_uint and t_INT types are very similar.
- Use the wrappers associated to the types number and field_elt.
- For all functions concerning multi-precision and modular arithmetic, use the PARI equivalent:
  ex: Fp_add for modular addition.
- The arithmetic of curves is completely independent of the library which is used for field arithmetic.

Exemple (1)

```
#if USE_BIG_UINT == 1

#include "big_uint.h"
typedef big_uint number;
typedef big_uint_t number_t;
#define LIMB(x) x->limb
#define SIZ(x) x->size
#define SIGN(x) x->sign

#else

#include <pari/pari.h>
typedef GEN number[1];
typedef GEN number_t;
#define LIMB(x) ((*x) + 2)
#define SIZ(x) (lg(*x) - 2)
#define SIGN(x) signe(*x) != 0 ? signe(*x) : 1

#endif
```

Exemple (2)

```
int8_t
number_cmp (const number src1, const number src2)
{
#if USE_BIG_UINT == 1
    return u_cmp(src1, src2);
#elif USE_GMP == 1
    return mpz_cmp(src1, src2);
#else
    return cmpii(*src1, *src2);
#endif
}
```

Performances

Processor : Intel core i7-4790 3.4 Ghz
Compiler : gcc-5.3.0 bootstrapped
PARI 2.7.5 and GMP 6.1.0
Tests with NIST and Brainpool curves.

Arithmetic functions

- Slowdown of about 30% using `GEN` version instead of the `big_uint` one.
- The management of the stack can be responsible for this slowdown.
- Work is in progress to improve the performances.

Comparison with ell* functions

- using big_uint : between 40 and 50% better.
- using GEN : between 20 and 30% better.

Comparison with FpE_* functions

- using big_uint : between 20 and 30% better.
- using GEN : between 0 and 10% better.

Remarks

- The improvements are better for addition and doubling than for scalar multiplication because only the naive implementation has been tested.
- We expected an increase with the other scalar multiplication implemented.
- The best results are obtained on large curves like NIST-384 and NIST-521.

Conclusion

- High performance library which deals with different coordinates systems and families of curves.
- The modularity of MPHELL allows to plug other libraries.
- It can be seen as a test platform for the arithmetic of unsupported curves.

Work in progress

- ARM V7 architecture.
- Finalisation of the integration on PARI library.


Thank You !