Contents

1 include/binio.hpp

```
/*
 * Toy Compression - Toy Compression Code
 * Written in 2018 by Gerald Lewis <lewisgdljr@gmail.com>
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 */

#pragma once
#ifndef BINIO_HPP
#define BINIO_HPP

#include <cstdint>
#include <iostream>
#include <iterator>
#include <limits>
#include <utility>

namespace binio {
   template <typename Iterator, typename Iterator2>
   struct bit_reader {
      Iterator      pos;
      Iterator2     end;
      std::uint8_t  buf;
      std::uint64_t total_count;
      unsigned int  bits_left;

      bit_reader( Iterator&& begin_, Iterator2&& end_ ) :
         pos{begin_},
         end{end_},
         buf{0},
         total_count{0},
         bits_left{0} {}

      void input_byte() {
         if ( pos == end ) {
            throw std::out_of_range(
               "Attempt to read bits beyond end of range" );
         }
         bits_left = std::numeric_limits<std::uint8_t>::digits;
         buf       = *pos;
         ++pos;
      }

      bool read_bit() {
         if ( bits_left == 0 ) {
            input_byte();
         }
         ++total_count;
         --bits_left;
         return ( buf >> bits_left ) & 1;
```

```
   }

   template <typename T>
   T read_bits( unsigned int bits ) {
      using UT = std::make_unsigned_t<T>;
      UT temp{0};
      for ( unsigned int i = 0; i < bits; i++ ) {
         temp = ( temp << 1 ) | read_bit();
      }
      return temp;
   }
};

template <typename Iterator, typename Iterator2,
          typename
          = typename std::iterator_traits<Iterator>::iterator_category>
auto make_bit_reader( Iterator&& begin, Iterator2&& end )
   -> bit_reader<Iterator, Iterator2> {
   return bit_reader<Iterator, Iterator2>{std::forward<Iterator>( begin ),
                                          std::forward<Iterator2>( end )};
}

template <typename Container,
          typename = decltype( std::declval<Container>().cbegin() )>
auto make_bit_reader( Container const& c ) {
   return make_bit_reader( c.cbegin(), c.cend() );
}

template <typename stream_t>
auto make_bit_reader( stream_t& stream ) -> decltype(
   make_bit_reader( std::istream_iterator<unsigned char>( stream ),
                    std::istream_iterator<unsigned char>() ) ) {
   return make_bit_reader( std::istream_iterator<unsigned char>( stream ),
                           std::istream_iterator<unsigned char>() );
}

template <typename Iterator>
struct bit_writer {
   Iterator      pos;
   std::uint8_t  buf;
   std::uint64_t total_count;
   unsigned int  bits_left;
   bit_writer( Iterator&& begin_ ) :
      pos{std::forward<Iterator>( begin_ )},
      buf{0},
      total_count{0},
      bits_left{std::numeric_limits<std::uint8_t>::digits} {}
   ~bit_writer() {
      if ( bits_left != std::numeric_limits<std::uint8_t>::digits ) {
         flush();
      }
   }
   bit_writer( bit_writer const& )  = delete;
   bit_writer( bit_writer const&& ) = delete;
   operator=( bit_writer const& ) = delete;
   operator=( bit_writer const&& ) = delete;
```

```
      void output_byte() {
         *pos = buf;
         buf  = 0;
         ++pos;
         bits_left = std::numeric_limits<std::uint8_t>::digits;
      }

      void write_bit( bool bit ) {
         --bits_left;
         ++total_count;
         buf |= ( static_cast<std::uint8_t>( bit ) << bits_left );
         if ( bits_left == 0 ) {
            output_byte();
         }
      }

      template <typename T, typename UT = std::make_unsigned_t<T>>
      void write_bits( T value, unsigned int num_bits ) {
         for ( int i = num_bits; i > 0; --i ) {
            UT mask = static_cast<UT>( 1 ) << ( i - 1 );
            write_bit( ( static_cast<UT>( value ) & mask ) != 0 );
         }
      }

      void flush() { output_byte(); }
   };

   template <typename Iterator,
             typename
             = typename std::iterator_traits<Iterator>::iterator_category>
   auto make_bit_writer( Iterator&& begin ) -> bit_writer<Iterator> {
      return bit_writer<Iterator>{std::forward<Iterator>( begin )};
   }

   template <typename Container,
             typename = decltype( std::declval<Container>().begin() )>
   auto make_bit_writer( Container&& c ) {
      return make_bit_writer( std::back_inserter( c ) );
   }

   template <typename stream_t>
   auto make_bit_writer( stream_t& stream ) -> decltype(
      make_bit_writer( std::ostream_iterator<unsigned char>( stream ) ) ) {
      return make_bit_writer( std::ostream_iterator<unsigned char>( stream ) );
   }
} // namespace binio

#endif // BINIO_HPP
```

2 include/codecs.hpp

```
/*
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 */

#pragma once
#ifndef CODECS_HPP_INCLUDED
#define CODECS_HPP_INCLUDED

#ifndef BINIO_HPP
#include "binio.hpp"
#endif // BINIO_HPP

#ifndef INTEGER_CODES_HPP
#include "integer_codes.hpp"
#endif // INTEGER_CODES_HPP

#endif // CODECS_HPP_INCLUDED
```

3 include/integer_codes.hpp

```
/*
 * Toy Compression - Toy Compression Code
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 */

#pragma once
#ifndef INTEGER_CODES_HPP
#define INTEGER_CODES_HPP

#include <cmath>
#include <exception>
#include <type_traits>

namespace integer_codes {
   struct unary {
      template <typename T, typename Iterator,
                typename = std::enable_if_t<std::is_unsigned_v<T>>>
      static void encode( T x, binio::bit_writer<Iterator>& storage ) {
         if ( x == 0 ) {
            throw std::invalid_argument( "unary code can't encode 0" );
         }
         T temp{x};
         while ( temp > 1 ) {
            --temp;
            storage.write_bit( 0 );
         }
         storage.write_bit( 1 );
      }

      template <typename T, typename Iterator, typename Iterator2,
                typename = std::enable_if_t<std::is_unsigned_v<T>>>
      static T decode( binio::bit_reader<Iterator, Iterator2>& storage ) {
         T temp{1};
         while ( !storage.read_bit() ) {
            ++temp;
         }
         return temp;
      }
   };

   struct truncated_binary {
      template <typename T, typename Iterator,
                typename = std::enable_if_t<std::is_unsigned_v<T>>>
      static void encode( T x, T n, binio::bit_writer<Iterator>& storage ) {
         if ( n == 0 ) {
            throw std::invalid_argument(
               "for the truncated binary code, n can't be 0" );
         }
```

```
      T    k      = static_cast<T>( std::floor( std::log2( n ) ) );
      T    u      = ( 1 << ( k + 1 ) ) - n;
      bool lesser = x < u;
      x           = lesser ? x : x + u;
      k           = lesser ? k : k + 1;
      storage.write_bits( x, k );
   }

   template <typename T, typename Iterator, typename Iterator2,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static T decode( T n, binio::bit_reader<Iterator, Iterator2>& storage ) {
      if ( n == 0 ) {
         throw std::invalid_argument(
            "for the truncated binary code, n can't be 0" );
      }
      T    k          = static_cast<T>( std::floor( std::log2( n ) ) );
      T    u          = ( 1 << ( k + 1 ) ) - n;
      T    x          = storage.template read_bits<T>( k );
      bool greater_eq = x >= u;
      x = greater_eq ? ( ( x << 1 ) | storage.read_bit() ) - u : x;
      return x;
   }
};

struct elias_gamma {
   template <typename T, typename Iterator,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static void encode( T x, binio::bit_writer<Iterator>& storage ) {
      if ( x == 0 ) {
         throw std::invalid_argument( "elias gamma code can't encode 0" );
      }

      T b = 1 + static_cast<T>( std::floor( std::log2( x ) ) );
      unary::template encode<T>( b, storage );
      storage.write_bits( x - ( 1 << ( b - 1 ) ), b - 1 );
   }

   template <typename T, typename Iterator, typename Iterator2,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static T decode( binio::bit_reader<Iterator, Iterator2>& storage ) {
      T b = unary::template decode<T>( storage );
      T x = storage.template read_bits<T>( b - 1 );
      return ( 1 << ( b - 1 ) ) + x;
   }
};

struct elias_delta {
   template <typename T, typename Iterator,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static void encode( T x, binio::bit_writer<Iterator>& storage ) {
      if ( x == 0 ) {
         throw std::invalid_argument( "elias delta code can't encode 0" );
      }
      T b = 1 + static_cast<T>( std::floor( std::log2( x ) ) );
      elias_gamma::template encode<T>( b, storage );
      storage.template write_bits<T>( ( x - ( 1 << ( b - 1 ) ) ), b - 1 );
```

```
   }

   template <typename T, typename Iterator, typename Iterator2,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static T decode( binio::bit_reader<Iterator, Iterator2>& storage ) {
      T b = elias_gamma::template decode<T>( storage );
      T x = storage.template read_bits<T>( b - 1 );
      return ( 1 << ( b - 1 ) ) + x;
   }
};

struct golomb {
   template <typename T, typename Iterator,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static void encode( T x, T b, binio::bit_writer<Iterator>& storage ) {
      if ( ( x == 0 ) || ( b == 0 ) ) {
         throw std::invalid_argument(
            "golomb code can't encode 0, and can't "
            "encode with golomb parameter 0" );
      }

      T q = ( x - 1 ) / b;
      T r = ( x - 1 ) % b;
      unary::template encode<T>( q + 1, storage );
      truncated_binary::template encode<T>( r, b, storage );
   }

   template <typename T, typename Iterator, typename Iterator2,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static T decode( T b, binio::bit_reader<Iterator, Iterator2>& storage ) {
      if ( b == 0 ) {
         throw std::invalid_argument(
            "golomb code can't decode with golomb parameter 0" );
      }

      T q = unary::template decode<T>( storage ) - 1;
      T r = truncated_binary::template decode<T>( b, storage );
      return r + ( q * b ) + 1;
   }
};

struct rice {
   template <typename T, typename Iterator,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static void encode( T x, T k, binio::bit_writer<Iterator>& storage ) {
      if ( x == 0 ) {
         throw std::invalid_argument( "rice code can't encode 0" );
      }

      T b = 1 << k;
      golomb::encode( x, b, storage );
   }

   template <typename T, typename Iterator, typename Iterator2,
             typename = std::enable_if_t<std::is_unsigned_v<T>>>
   static T decode( T k, binio::bit_reader<Iterator, Iterator2>& storage ) {
      T b = 1 << k;
```

```
        return golomb::template decode<T>( b, storage );
      }
   };
} // namespace integer_codes

#endif // INTEGER_CODES_HPP
```

4 test/test.cpp

```
/*
 * Toy Compression - Toy Compression Code
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 */

#include "codecs.hpp"
#include "testing.hpp"
#include <cstdint>
#include <iomanip>
#include <ios>
#include <iostream>
#include <sstream>
#include <vector>

using container = std::vector<std::uint8_t>;
using iterator  = typename container::iterator;

using test_type = unsigned;

using binio::make_bit_reader;
using binio::make_bit_writer;

toy_test::test_suite bit_reader_suite
   = {"Test for bit_reader",
      {
         {"bit_reader can be created from a pair of iterators",
          [] {
             container c( 100 );
             (void)make_bit_reader( c.begin(), c.end() );
             ASSERT( true );
          }},

         {"bit_reader can be created from a container",
          [] {
             container c( 100 );
             (void)make_bit_reader( c );
             ASSERT( true );
          }},

         {"bit_reader can be created from an istream",
          [] {
             std::istringstream ss;
             (void)make_bit_reader( ss );
             ASSERT( true );
          }},

         {"bit_reader throws exception when read from empty",
          [] {
```

```
            container c{};
            auto      reader = make_bit_reader( c );
            THROWS( reader.read_bit(), std::out_of_range );
         }},

         {"bit_reader.read_bit() returns the first available bit",
          [] {
            container c{0x70};
            auto      reader = make_bit_reader( c );
            ASSERT( reader.read_bit() == 0 );
         }},

         {"bit_reader.read_bits() returns multiple bits",
          [] {
            container c{0x70, 0x0f, 0x0};
            auto      reader = make_bit_reader( c );
            (void)reader.read_bit();
            auto temp = reader.read_bits<test_type>( 16 );
            ASSERT( temp == 0xe01e );
         }},

      }};

toy_test::test_suite bit_writer_suite
   = {"Test for bit_writer",
      {
         {"bit_writer can be created from an iterator",
          [] {
            container c;
            (void)make_bit_writer( std::back_inserter( c ) );
            ASSERT( true );
         }},

         {"bit_writer can be created from a container",
          [] {
            container c;
            (void)make_bit_writer( c );
            ASSERT( true );
         }},

         {"bit_writer can be created from an ostream",
          [] {
            std::ostringstream ss;
            {
               auto writer = make_bit_writer( ss );
               for ( int i = 0; i < 10; i++ ) {
                  writer.write_bit( 1 );
               }
            }
            { (void)make_bit_writer( ss ); }

            ASSERT( true );
         }},

         {"bit_writer.write_bit() writes a bit to the buffer",
          [] {
            container c;
```

```
            auto      writer = make_bit_writer( c );
            writer.write_bit( 1 );
            writer.write_bit( 1 );
            writer.write_bit( 1 );
            writer.write_bit( 0 );
            writer.flush();
            ASSERT( c[0] == 0xe0 );
         }},

         {"bit_writer.write_bits() writes a group of bits to the buffer",
          [] {
            container c;
            auto      writer = make_bit_writer( c );
            writer.write_bits<test_type>( 0xfaf, 12 );
            writer.flush();
            ASSERT( ( c[0] == 0xfa ) && ( c[1] == 0xf0 ) );
         }},

         {"bit_writer flushes partial bytes to the buffer",
          [] {
            container c;
            {
               auto writer = make_bit_writer( c );
               writer.write_bit( 1 );
               writer.write_bit( 1 );
            }
            ASSERT( c[0] == 0xc0 );
         }},
      }};

void test_unary_coder( test_type value ) {
   container c;
   {
      auto writer = make_bit_writer( c );
      integer_codes::unary::encode( value, writer );
   }
   auto reader  = make_bit_reader( c );
   auto decoded = integer_codes::unary::decode<test_type>( reader );
   ASSERT( decoded == value );
}

toy_test::test_suite unary_suite
   = {"test for unary coder",
      {
         {"throws an exception for x=0",
          [] {
            container c;
            auto      writer = make_bit_writer( c );
            THROWS( integer_codes::unary::encode<test_type>( 0, writer ),
                    std::invalid_argument );
         }},
         {"encodes a one-value", [] { test_unary_coder( 1 ); }},
         {"encodes a small integer", [] { test_unary_coder( 2 ); }},
         {"encodes another small integer", [] { test_unary_coder( 5 ); }},
      }};

void test_truncated_binary_coder( test_type value, test_type n ) {
```

```
   container c;
   {
      auto writer = make_bit_writer( c );
      integer_codes::truncated_binary::encode( value, n, writer );
   }
   auto reader = make_bit_reader( c );
   auto decoded
      = integer_codes::truncated_binary::decode<test_type>( n, reader );
   ASSERT( decoded == value );
}

toy_test::test_suite truncated_binary_suite
   = {"Test for truncated binary coder",
      {
         {"encode() throws an exception for n = 0",
          [] {
             container c;
             auto      writer = make_bit_writer( c );
             THROWS( integer_codes::truncated_binary::encode<test_type>(
                        1, 0, writer ),
                     std::invalid_argument );
          }},

         {"decode() throws an exception for n = 0",
          [] {
             container c( 100 );
             auto      reader = make_bit_reader( c );
             THROWS(
                integer_codes::truncated_binary::decode<test_type>( 0, reader ),
                std::invalid_argument );
          }},

         {"encodes a value of 3 using n = 6",
          [] { test_truncated_binary_coder( 3, 6 ); }},

         {"encodes a value of 3 using n = 4",
          [] { test_truncated_binary_coder( 3, 4 ); }},

         {"encodes a value of 3 using n = 8",
          [] { test_truncated_binary_coder( 3, 8 ); }},

         {"encodes a value of 7 using n = 8",
          [] { test_truncated_binary_coder( 7, 8 ); }},

      }};

void test_elias_gamma_coder( test_type value ) {
   container c;
   {
      auto writer = make_bit_writer( c );
      integer_codes::elias_gamma::encode( value, writer );
   }
   auto reader  = make_bit_reader( c );
   auto decoded = integer_codes::elias_gamma::decode<test_type>( reader );
   ASSERT( decoded == value );
}
```

```
toy_test::test_suite elias_gamma_suite
   = {"Test for elias gamma coder",
      {
         {"throws an exception for x=0",
          [] {
             container c;
             auto      writer = make_bit_writer( c );
             THROWS( integer_codes::elias_gamma::encode<test_type>( 0, writer ),
                     std::invalid_argument );
          }},
         {"encodes a value of 2", [] { test_elias_gamma_coder( 2 ); }},
         {"encodes a value of 3", [] { test_elias_gamma_coder( 3 ); }},
      }};

void test_elias_delta_coder( test_type value ) {
   container c;
   {
      auto writer = make_bit_writer( c );
      integer_codes::elias_delta::encode( value, writer );
   }
   auto reader  = make_bit_reader( c );
   auto decoded = integer_codes::elias_delta::decode<test_type>( reader );
   ASSERT( decoded == value );
}

toy_test::test_suite elias_delta_suite
   = {"Test for elias delta coder",
      {
         {"throws an exception for x=0",
          [] {
             container c;
             auto      writer = make_bit_writer( c );
             THROWS( integer_codes::elias_delta::encode<test_type>( 0, writer ),
                     std::invalid_argument );
          }},

         {"encodes a value of 1", [] { test_elias_delta_coder( 1 ); }},
         {"encodes a value of 3", [] { test_elias_delta_coder( 3 ); }},
      }};

void test_golomb( test_type x, test_type b ) {
   container c;
   {
      auto writer = make_bit_writer( c );
      integer_codes::golomb::encode( x, b, writer );
   }
   auto reader = make_bit_reader( c );
   auto result = integer_codes::golomb::template decode<test_type>( b, reader );
   ASSERT( result == x );
}

toy_test::test_suite golomb_suite
   = {"Test for golomb coder",
      {
         {"encode throws an exception for x=0",
          [] {
             container c;
```

```
            auto      writer = make_bit_writer( c );
            THROWS( integer_codes::golomb::encode<test_type>( 0, 5, writer ),
                    std::invalid_argument );
         }},

         {"encode throws an exception for b=0",
          [] {
            container c;
            auto      writer = make_bit_writer( c );
            THROWS( integer_codes::golomb::encode<test_type>( 5, 0, writer ),
                    std::invalid_argument );
         }},

         {"decode throws an exception for b=0",
          [] {
            container c( 100 );
            auto      reader = make_bit_reader( c );
            THROWS( integer_codes::golomb::decode<test_type>( 0, reader ),
                    std::invalid_argument );
         }},

         {"encodes and decodes small integers",
          [] {
            for ( test_type i = 1; i < 256; i++ ) {
               for ( test_type b = 1; b < 256; b++ ) {
                  test_golomb( i, b );
               }
            }
         }},
      }};

void test_rice( test_type x, test_type b ) {
   container c;
   {
      auto writer = make_bit_writer( c );
      integer_codes::rice::encode( x, b, writer );
   }
   auto reader = make_bit_reader( c );
   auto result = integer_codes::rice::template decode<test_type>( b, reader );
   ASSERT( result == x );
}

toy_test::test_suite rice_suite
   = {"Test for rice coder",
      {
         {"throws an exception for x=0",
          [] {
            container c( 100 );
            auto      writer = make_bit_writer( c );
            THROWS( integer_codes::rice::encode<test_type>( 0, 4, writer ),
                    std::invalid_argument );
         }},

         {"encodes and decodes small integers",
          [] {
            for ( test_type i = 1; i < 256; i++ ) {
               for ( test_type k = 0; k < 16; k++ ) {
```

```
                test_rice( i, k );
            }
        }
    }},
}};

int main() {
    toy_test::run_suites( {bit_reader_suite, bit_writer_suite, unary_suite,
                           truncated_binary_suite, elias_gamma_suite,
                           elias_delta_suite, golomb_suite, rice_suite} );
}
```

5 test/testing.hpp

```
/*
 * Toy Test - Toy Unit Testing
 * Written in 2018 by Gerald Lewis <lewisgdljr@gmail.com>
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 */

#pragma once
#ifndef TESTING_HPP_INCLUDED
#define TESTING_HPP_INCLUDED

#include <functional>
#include <initializer_list>
#include <iostream>
#include <vector>

namespace toy_test {
   struct test_case {
      const char*           name;
      std::function<void()> run;
      void                  operator()() const { run(); }
   };

   struct failure {
      const char* expr;
      int         line;
   };

   struct test_suite {
      const char*            name;
      std::vector<test_case> tests;

      bool run() const {
         bool ok{true};
         std::cout << "[SUITE] Running test suite: \"" << name << "\""
                   << std::endl
                   << std::endl;
         for ( auto&& test : tests ) {
            try {
               test();
               std::cout << "[OK.] \"" << test.name << "\" passed."
                         << std::endl;
            } catch ( failure& caught ) {
               ok = false;
               std::cout << "[FAIL!] \"" << test.name << "\" failed."
                         << std::endl;
               std::cout << "Failing condition: \"" << caught.expr
                         << "\" at line: " << caught.line << std::endl;
            }
         }
```

```
        if ( ok ) {
            std::cout << std::endl
                      << "[OK] All tests passed for suite: \"" << name << "\""
                      << std::endl;
        } else {
            std::cout << std::endl
                      << "[FAIL!] Test failures detected in suite: \"" << name
                      << "\"" << std::endl;
        }
        return ok;
    }
};

bool run_suite( test_suite const& suite ) { return suite.run(); }

bool run_suites( std::initializer_list<test_suite const> const suites ) {
    bool ok = true;
    for ( auto const& a : suites ) {
        ok &= run_suite( std::forward<test_suite const>( a ) );
    }

    if ( ok ) {
        std::cout << std::endl
                  << "[OK] All tests passed." << std::endl
                  << std::endl;
    } else {
        std::cout << std::endl
                  << "[FAIL!] Test failures detected." << std::endl
                  << " Check the output for details." << std::endl
                  << std::endl;
    }
    return ok;
}

#define ASSERT( condition )                          \
    void( ( condition ) ? 0                          \
                        : throw toy_test::failure( \
                              {"ASSERT(" #condition ")", __LINE__} ) )

#define THROWS( expression, exception )                                  \
    try {                                                                \
        ( expression );                                                  \
        throw toy_test::failure(                                         \
            {"THROWS(" #expression ", " #exception ")", __LINE__} ); \
    } catch ( exception& ) {                                             \
    } catch ( ... ) {                                                    \
        throw toy_test::failure(                                         \
            {"THROWS(" #expression ", " #exception ")", __LINE__} ); \
    }
} // namespace toy_test
#endif // TESTING_HPP_INCLUDED
```