# Ph.D. Project :
# Design-Space Exploration for Error-Correction Solutions

ÉCOLE DE TECHNOLOGIE SUPÉRIEURE
Université du Québec
Engineering for Industry

## General Information

**Research area:** Error-correction coding, design-space exploration, compiler design, and hardware architecture
**Supervisor:** Prof. Pascal Giard <pascal.giard@etsmtl.ca>
**Institution:** École de technologie supérieure, Montréal, Québec, Canada
**Start date:** Fall 2026 or as early as possible

## Context

Error-correction coding is a critical component of modern communication and storage systems, enabling the detection and correction of data corruption. There are numerous families of error-correcting codes (e.g., Hamming, Reed-Solomon, Turbo, LDPC, Polar), each offering distinct advantages. Each code family may allow multiple decoding algorithms, which can in turn be implemented with different hardware architectures, schedules, quantization schemes, and technology nodes. This results in an immense design space where finding the solution that best meets application requirements is a complex and challenging task.

Design-space exploration (DSE) offers a systematic approach to navigate this complexity by evaluating and optimizing various decoding algorithms and hardware configurations. However, automating DSE specifically for error correction, where the best candidates are identified by evaluating key performance indicators (KPIs) across multiple abstraction levels, remains an open challenge.

This project is part of an NSERC Discovery research program whose long-term objective is to create an open ecosystem for the design-space exploration of error-correction solutions, enabling the informed selection of a code along with the decoding algorithm and hardware architecture, all the way down to the autogeneration of the associated circuits. Furthermore, this program involves collaborations with Prof. François Leduc-Primeau (Polytechnique Montréal), Prof. Camille Leroux (Bordeaux INP, France), and Prof. Stefan Weithoffer (IMT Atlantique, France). Depending on the research direction and the student's interests, opportunities for co-supervision, close collaboration, or international research stays may be available.

## Project Objectives

The primary objective of this project is to investigate, design, and develop the foundations for design-space exploration tailored to error correction. More specifically, the project aims to:

- Conduct an in-depth analysis of error-correction techniques, identifying KPIs for various applications, code families, decoding algorithms, and hardware implementations.
- Design and develop a modular DSE framework specific to error correction, separating components such as codes and their design constraints, compiler and KPI estimation, visualization tools, and optimization algorithms.
- Research the creation of domain-specific intermediate representations (IRs) capable of capturing the design space, including data dependencies, resource allocation, and scheduling information.
- Design a compiler that translates user inputs (e.g., code family, code parameters, decoding algorithms) into models represented in these IRs, with support for multiple code families.
- Incorporate constraint-handling mechanisms to allow users to specify hard and soft constraints, explore trade-offs, and conduct multi-objective optimization.

## Expected Contributions

In addition to the doctoral thesis, the project is expected to result in multiple significant contributions disseminated in peer-reviewed publications. Furthermore, here are examples of potential technical contributions tied to this project:

- A modular, open DSE framework for error-correction solutions spanning multiple code families.
- Domain-specific IRs and a compiler for error-correction design spaces.
- KPI estimation models validated against real-world benchmarks and, where possible, actual measurements.
- Visualization aids to facilitate the interpretation of KPI data and the exploration of trade-offs.

## Desired Profile

- Student in electrical engineering, computer engineering, or a closely related field.
- Solid background in error-correction coding (e.g., LDPC, Polar, Turbo codes) or digital communications.
- Strong programming skills.
- Interest in compiler design, algorithm development, and optimization techniques.
- Interest in hardware design and implementation is desirable.

The following skills are considered assets:

- Experience with DSE tools or frameworks.
- Experience with hardware description languages, e.g., VHDL or Verilog.
- Familiarity with multi-objective optimization methods.
- Prior experience with tools such as AFF3CT or similar error-correction simulation platforms.

## Supervision

Supervision will be provided by Professor Pascal Giard. Dr. Giard is a professor in the Department of Electrical Engineering at ÉTS. His research focuses on the efficient implementation of digital systems, from algorithm design to software and hardware realization. He has extensive experience in error-correction coding, hardware architecture design, and the development of design-space exploration tools.

The selected candidate will join a team of graduate student researchers working on closely related topics.

**Pascal Giard**

## Funding and Duration

The project is funded for a duration of four years and includes financial support for the student's stipend as well as research-related expenses, including international conference travel.

## Location

ÉTS is located in Montréal, Québec, Canada. Often described as an appealing blend of North American and European culture, Montréal is a safe, multicultural city with a high quality of life and a relatively affordable cost of living. It is the most bilingual and trilingual city in North America: over 50% of Montréalers are fluent in both English and French, and more than 20% speak three or more languages.

Since 2016, Montréal has consistently been ranked the best student city in North America by Quacquarelli Symonds. The city is also well known for its quality of life, proximity to both peaceful rural landscapes and exciting ski resorts, and its vibrant neighborhoods and green spaces. Located in the heart of the city, the ÉTS campus is easily accessible by bicycle or public transportation. Approximately 1,100 students live in the university residences, which include furnished studios and apartments with heating, electricity, and unlimited Internet access.

Since its founding, ÉTS has pursued a mission deeply rooted in all of its activities: addressing the needs of industry, which requires engineers with not only strong theoretical foundations but also practical expertise. To fulfill this mission, ÉTS maintains a unique partnership with the business and industrial sectors, from small enterprises to large corporations. It distinguishes itself from other Québec universities through its applied education model and its research activities conducted by and for industry.

## Interested?

Interested candidates should submit their CV, academic transcripts, contact information for appropriate references, and a brief statement of interest (maximum one page) describing how their background is relevant to this project.

**Contact:** Prof. Pascal Giard <pascal.giard@etsmtl.ca>
**Start date:** Fall 2026 or as early as possible