Mitacs
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Mitacs Accelerate Proposal

INSTRUCTIONS

- Please make sure you are using the latest version of this form posted on **https://www.mitacs.ca/en/programs/accelerate/proposal.** This link also provides an Accelerate Guide with detailed information on how to write your proposal.
- Please **do not modify, remove** text or instructions in each section/subsection **or reformat** this form in any way. A modified form will result in a delay in the internship evaluation process.
- Send your draft proposal to your Mitacs Business Development representative **prior** to obtaining all signatures and submitting.
- The proposal should be written and submitted **at least eight (8) weeks prior to the planned start date of the internship. For international travel, a minimum of 16 weeks lead time is required.**
- The start date of the internship must be **after** research approval and the **receipt** of the partner funds at Mitacs.
- Partner funds can be sent directly to Mitacs in Canadian dollars prior to approval to expedite the process.
- If applicable, proposals with a not-for-profit, hospital, or municipality as a partner organization must seek partner and project eligibility approval before proceeding. Please contact a Mitacs Business Development representative to discuss eligibility **BEFORE** submitting your application.
- If applicable, intern conflict of interest declarations must be received by Mitacs before submitting your application.
- If applicable, academic supervisor conflict of interest documentation must be submitted with your application. For more information, see Mitacs's Conflict of Interest policy: http://www.mitacs.ca/en/conflict-interest-policy.
- If you cannot see the items listed in the drop-down lists, please refer to Appendix C: Options and type the corresponding answer in the space provided.

Please note: If required, your **Mitacs Business Development representative** can assist you with:

- Identifying your Office of Research Services (ORS) or equivalent representative.
- Assessing the eligibility and completeness of the proposed research.

APPLICATION CHECKLIST

A complete internship application package must include the following:

- The proposal **completed and signed** by all parties in Word format
  - *The Mitacs Accelerate Memorandum* (Section 7) with signatures must be submitted as a scanned PDF
  - Appendix A - *Accelerate Intern Consent Form* signed
- Intern(s) CV (Any format is allowed. A CV template is available on the Mitacs website)
- Lead academic supervisor's CV for each participating academic institution **only** for projects with **6+ IUs** (CCV as per Tri-Agency or other CV format)
- Accelerate budget and invoicing schedule (Excel spreadsheet)
- Any supplementary documents (as applicable)

If your application involves any international collaboration, please note:

- You must complete Appendix B – *Mitacs Accelerate: International Collaboration Form* in addition to this entire application
- International Pre-Departure Form and Code of Conduct and Ethics form may be forwarded to Mitacs after submission of your application; however, funds cannot be released, and the internship may not begin until Mitacs receives these forms
- Indemnity Agreement (as applicable) *Please contact your Business Development representative to find out whether this document is required
- Visit the Accelerate International website to determine if there is any additional required documentation for the country you intend to work with

* **An incomplete application or a modified form will result in a delay in the proposal evaluation process.**

Mitacs Accelerate Proposal

1. Research proposal summary

1.1.	**Title of project:**	Hardware accelerated collision checking for robotics		
1.2.	**Type of project:** Select all that apply	☒ Accelerate		
		☐ Accelerate Fellowship		
		☐ Accelerate Entrepreneur		
		☐ Accelerate International (Please also complete Appendix B)		
1.3.	**Keywords to identify reviewers:** (5-10 specific keywords; 50% technically and/or conceptually related, 50% discipline-related)	Motion Planning, Collision Checking, Rigid-body Dynamics, Hardware Acceleration, Parallel Processing, Robotic Manipulators, Robotics		
1.4.	**Academic discipline:**	Computer Science		
1.5.	**Project priority sectors:**	Artificial intelligence	Technology	3rd Priority Sector

1.6. List of participants:

Academic supervisor(s)	**Department or Faculty**	**Academic institution**	**City and country location of academic institution**
Professor. Nandita Vijaykumar	Computer Science	University of Toronto	Toronto, ON, Canada
Partner organization(s)	**Contact name at partner organization**	**City and country location of organization**	**Partner legal status**
Kindred AI	Kevin George	Toronto, Ontario	For Profit Corporation
			Select Legal Status

1.7 Proposed work plan for internship unit(s) (IU):

Please summarize the work plan for the project by showing which intern will work when. Each internship unit (IU) corresponds to one 4-6-month internship. This table provides a high-level overview of the proposed research project and information about intern(s) to the reviewers. Please refer to the **Accelerate Guide: Writing your proposal** for assistance.

			Year 1			Year 2			Year 3			Year 4			Year 5		
			1-4	5-8	9-12	1-4	5-8	9-12	1-4	5-8	9-12	1-4	5-8	9-12	1-4	5-8	9-12
Intern name	**Degree program**	**IU**															
Sumant Bagri	MScAC	2	X	X													
Total internship units		**2**															
Total project funding	**$30,000**																

2. Description of proposed research

2.1. **Research abstract** (approx. 200 words):

Please include: Research problem to be addressed and its significance, objectives, and proposed methodology. This section will be used to recruit reviewers; it differs from section 7.2. (Public project overview) and must clearly summarize the research proposed.

The ability to perform collision checking quickly and accurately is critical for robotic applications that rely on path planning, forward kinematics, and inverse kinematics. However, most of the time spent during path planning is dedicated to collision checking, which limits the feasibility of planning in real-time and the quality of the plans produced. The aim of this project is to prototype a hardware-accelerated collision checking library that can leverage the faster vector operations of a specialized compute such as a GPU. To achieve this objective, an elaborate review of existing commercial and open-source collision checking libraries will be conducted in the beginning. Subsequently, the needs of robotics applications will be assessed and a collision checking solution will be selected and adapted to best satisfy the said objectives. Based on this, a minimum viable product (MVP) will be designed that will showcase the value of hardware acceleration for this problem.

Finally, the MVP will be integrated into a robotics platform, which will enable the organization to expand and refine the hardware-accelerated collision checking library for future use. Ultimately, this project aims to significantly improve the speed and accuracy of collision checking for robotic applications, which will enable more efficient and effective path planning, forward kinematics, and inverse kinematics.

2.2. **Background** and review of relevant prior work (minimum 500 words):

The ability to quickly determine whether a robot pose is in collision with environment geometry is critical for ensuring safe and efficient robot operations. Collision detection involves checking for intersection between the robot model and the environment model, which can be a computationally expensive task. In particular, during path planning, up to 99% of the time can be spent performing collision checks. Therefore, improving the speed of collision checking can have a significant impact on the feasibility of planning in real-time and the quality of the plans produced.

One of the key algorithms for collision detection is the Gilbert–Johnson–Keerthi (GJK) algorithm [1] is a widely-used algorithm for collision detection between convex objects. It works by iteratively constructing a simplex, a shape with the fewest number of points that still contains the origin, until it encloses the intersection of the two objects. However, it can be computationally expensive and has limitations in slower performance, especially when used for complex models, such as robots with many links or articulated fingers. The Bounding Volume Hierarchy (BVH) algorithm [2] is a popular technique for collision detection that organizes complex geometric models into a tree-like hierarchy of bounding volumes. BVH traversal only tests primitives in the hierarchy which are close to each other, reducing the number of tests required. This makes it efficient for models with many primitives, like robots with many links or articulated fingers. Compared to the GJK algorithm, BVH traversal is less computationally expensive but less accurate.

However, collision detection remains a compute-intensive task during motion planning for complex environments with robotic manipulators having multiple degrees of freedom. Graphics processing units (GPUs) are highly parallel processors that can perform vector operations much faster than CPUs. This makes them ideal for performing collision detection calculations in real-time. Several research papers have explored the use of hardware acceleration for collision detection in robotic manipulators.

LE GRAND Scott [3] presents an optimized approach to perform broad-phase collision detection using CUDA, a parallel computing platform for GPUs. The proposed method leverages spatial hashing and parallel sorting techniques to accelerate the computation of collision pairs between objects. The results show significant speedup compared to CPU-based implementations and demonstrate the potential of GPU-based collision detection for robotics and gaming applications.

In another work, Lauterbach et al [4] present a parallel algorithm to construct bounding volume hierarchies (BVH) for accelerating collision detection using GPUs. The proposed method uses an efficient tree construction algorithm based on spatial splits and parallelizes the workload over multiple threads. The results demonstrate significant speedup compared to CPU-based implementations and show that the approach is scalable to handle large models with millions of triangles, making it suitable for real-time collision detection in robotics and gaming applications. Subsequently, they introduce gProximity [5], a GPU-accelerated framework for fast and accurate collision and distance queries between geometric models. The approach leverages hierarchical data structures such as bounding volume hierarchies and k-d trees to accelerate the computation of proximity queries on the GPU. The results demonstrate significant speedup compared to CPU-based methods and show that gProximity is capable of handling complex models with millions of triangles, making it suitable for real-time robotics applications.

Pan et al. [6] present a GPU-based parallel collision detection (PCD) approach for fast motion planning. They propose a hybrid parallel algorithm that combines the merits of the uniform grid and the object-level bounding volume hierarchy (BVH) for collision detection. The proposed approach is shown to be able to detect collisions between complex robots and their surrounding environment with high efficiency and accuracy. Experimental results demonstrate that the proposed approach outperforms existing methods on a variety of benchmarks, achieving speedups of up to 23 times compared to a CPU implementation. The approach is also shown to be scalable and able to handle large-scale problems with millions of triangles.

However, implementing such algorithms on GPUs for specialized robotic manipulators poses a significant challenge in terms of compatibility, scalability and reliability. Custom hardware may have unique architectural constraints that make it difficult to optimize collision checking algorithms or physics engines. Additionally, hardware acceleration may require significant modifications to existing algorithms, which can be time-consuming and complex. Finally, the trade-off between performance and accuracy in hardware-accelerated collision checking algorithms must be carefully considered, as inaccurate collision checking can result in damage to robots or their environment.
In conclusion, collision checking is a critical component of robotics applications, and there has been significant research into improving the efficiency and effectiveness of collision checking methods. Hardware acceleration, particularly through the use of GPUs, is an attractive approach to improving the speed of collision checking calculations. However, the key challenge in this project is going to be implementing such algorithms for specific robotic applications and environments.

2.3. **General objective** of the research project broken down into sub-objectives, activities, themes, or subprojects, as applicable:

The general objective of this project is to improve the performance of pick-and-place robotic manipulators during motion-planning by accelerating collision detection through the use of specialized compute like GPU such that the system is able to perform its tasks more effectively and efficiently while ensuring environmental safety by maintaining pre-defined clearance thresholds. Some of the key sub-objectives include, conducting a review of existing collision checking libraries available (commercial or open source), understanding the needs of robotics applications and deciding which collision checking solution would meet those needs, designing an MVP that can showcase the value of hardware acceleration f or this problem, integrating the MVP into the robotics platform so it can be expanded in the future for all the company's needs, and testing and optimizing the MVP for performance on a GPU platform. Ultimately, the project aims to build a more efficient methodology for conducting collision checking in robotic manipulators by using GPUs and potentially other hardware accelerators (such as FPGAs) and compare its performance with the existing implementations for some of Kindred's products.

2.4. Details of internships or subprojects:

For <u>each</u> intern or subproject, provide the following mandatory information:

a. Name of intern.

b. **Specific objectives of the internship or subproject**. Clearly state your [sub-] objectives so reviewers can assess if they are achievable.

1. Conduct a review of existing collision checking libraries available (commercial or open source)
2. Understand the needs of robotic system in terms of payload capacity, reach, speed, accuracy and flexibility and evaluating collision checking solutions based on those needs.
3. Determine which hardware accelerator would be most suitable for the robotic manipulator by evaluating its compatibility, clock-speed, memory-bandwidth and the trade-off between power consumption and floating-point performance.
4. Design a Minimum Viable Product (MVP) by adapting the best collision checking solution for the selected hardware-accelerator.
5. Test in a simulated environment and subsequently on the real hardware and perform explicit optimization as required.
6. Evaluate performance of the MVP for a set of pick-and-place tasks comparing it to existing implementations and showcase its advantages.
7. Integrate the MVP into the robotics platform so that it can be expanded in the future for other problems.

c. **Methodologies**. Provide enough detail so reviewers can determine if the proposed methodology is appropriate and sufficient to achieve the [sub-] objectives.

The first phase of the project would involve conducting a thorough literature review on different collision checking libraries. The review would focus on identifying key points such as the accuracy, computational complexity, and speed of the libraries. Two potential libraries that would be of interest are gPlanner and gProximity. The gPlanner library is designed for robot motion planning and uses a collision detection module for checking collisions. The gProximity library, on the other hand, is designed for proximity queries and can be used for detecting collisions. The review would help in identifying the most suitable library for the robotic manipulator.

The next task would involve evaluating the requirements of the robotic manipulator to determine the technical metrics to measure. Some of the technical metrics that may be measured include the workspace of the manipulator, the joint range, the degrees of freedom of the manipulator and the maximum payload capacity. These metrics would inform the design of the collision detection algorithm.

In the next phase, the task would be to determine which hardware accelerator to use by considering factors such as FLOPs, power consumption, and memory bandwidth. The chosen accelerator should be able to perform the collision detection algorithm efficiently and meet the requirements of the robotic manipulator.

After determining the appropriate library and hardware accelerator, the next step would be designing a parallelized algorithm for collision checking optimized for the organization's robotic manipulators. Several factors would be considered while designing the algorithm on a GPU, including global memory vs shared memory access, incoherent tree traversals due to different branching decisions, and skewed workloads across threads. Some potential techniques to address these issues would include using the parallel collision packet traversal algorithm and parallel collision query with workload balancing [6].

In the parallel collision packet traversal approach, each thread in a GPU block is responsible for checking the collisions between a single packet and the objects in the scene. The packets are typically small groups of triangles that represent a portion of the robot or other object being checked for collisions. Each thread loads the packet data into shared memory and then iterates over the objects in the scene, testing for collisions using a bounding volume hierarchy (BVH) data structure. To improve performance, the parallel collision packet traversal technique uses several optimizations. One optimization is to use a technique called warp-shuffle to perform a reduction

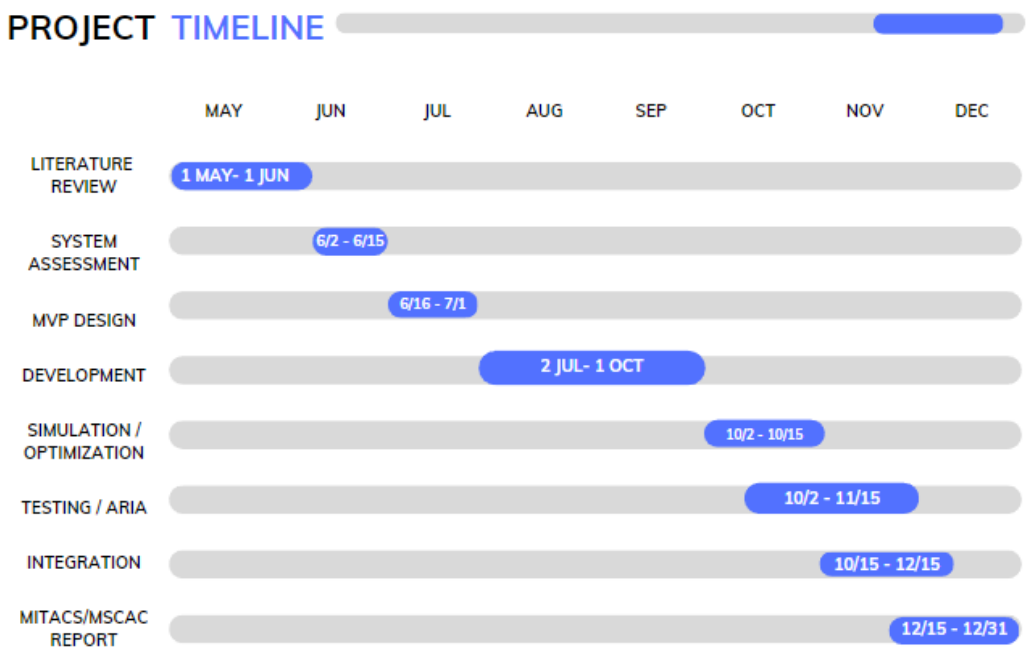
operation on the collision results of each thread within a warp. This allows the threads to quickly combine their collision results without having to communicate with threads in other warps. Another optimization is to use the texture cache of the GPU to store the BVH nodes, which reduces memory bandwidth requirements and improves performance.

Workload balancing on the threads would involve adapting the "Bin-packing workload balancing algorithm" introduced by Pan et al. [6]. This algorithm partitions the queries into a set of bins with a fixed maximum size and assigns each bin to a thread. The bin sizes are chosen such that the computational load of each thread is approximately equal. This balancing algorithm considers the complexity of each query and ensures that the threads do not become idle due to some queries taking longer to complete than others.

The algorithm would primarily be implemented using C++ and CUDA programming on a pre-selected NVIDIA GPU. The collision-checking module of gPlanner would be replaced with the new library. The Distributed Debugging Tool (DDT) would be used for debugging the program execution. NVIDIA Nsight would be used as a profiling tool to measure execution times and memory usage. In addition, the performance benchmarking suite would include Roofline Models and LogP models to provide a better insight into the algorithm's performance.

The final stage of the project would involve integrating the hardware accelerated collision checking library with the existing software stack of the organization. Potential issues that could arise during integration include compatibility issues, performance impacts, and bottlenecks. These would be addressed by running rigorous performance tests and optimizing some obvious bottlenecks as well as using virtualization techniques to isolate the libraries runtime environment such that it does not conflict with the existing software stack.

d. **Timeline.** We suggest using a Gantt chart to provide a timeline showing which task will be done when to achieve each objective.



e. **Expected deliverables.** Each project requires the submission of a completed Mitacs Final Report and Mitacs survey at the end of the project. Please describe the additional expected deliverables of the project

i.e., expected outcomes, results, documents (e.g., intern's thesis, peer-reviewed journal, teaching material, conference presentation, artistic production).

- Mitacs Final Report
- Mitacs survey
- Proposal/report for MScAC program
- Poster presentation at ARIA

f. Benefit to the intern.

As part of this internship, I will have an opportunity to work directly with Kindred AI's robotics platforms. I will also get to interact with highly skilled professionals working on cutting edge technologies in robotics. It will also bolster my foundations in GPU programming, motion-planning for specialized robots, computer graphics and high-performance computing.

I am currently pursuing a full-time career as a robotics software engineer in the field of ecommerce and healthcare and this internship is the perfect incubator for my future ambitions.

g. Interaction. Indicate the percentage (%) of time during the project that the intern will spend on-site at the partner organization location and at the academic institution(s). Research should be carried out equally (50%) in the premises of the partner organization and the academic institution(s).

(1) Partner interaction:

Interaction % at partner organization location in Canada	_75__ %
Interaction % at partner organization location abroad	___ %
Interaction % at academic institution in Canada	_25_ %
Interaction % at academic institution abroad	___ %
TOTAL (must equal 100%)	100%

(2) If the research is not carried out equally (50%) at the premises of the partner organization and academic institution(s), please include a justification. NOTE: The minimum interaction at either site is 25% with a maximum of 75%.

Majority of the work would involve probing, development and testing on Kindred's proprietary robotic systems and would therefore require spending a larger proportion of time on-site in Kindred's office. Also, it is advised by the industry supervisor that all project related meetings and discussions be conducted at the organization's office.

h. Partner interaction.

(1) Provide a detailed description of the activities that will be performed on-site at the partner organization and the expected interaction with and supervision by employees of the partner organization. For **Accelerate Entrepreneur** applicants, please provide a detailed description of the activities that will be performed on-site at the pre-approved incubator, including the expected interaction with and supervision with incubator staff.

I will be mentored by Kevin George from the Motion Platform team at Kindred AI. Kevin is Computer Scientist with more than a decade of industry experience in software engineering specifically in the field of Robotics. He is particularly skilled in C++ development for motion planning using the Robotic Operating System (ROS).

During my internship period, I will be working on gaining specific subject-matter expertise. I will also be co-ordinating my work with various members of the Motion Platform team in-order to develop, test and integrate the MVP for hardware accelerated collision checking for Kindred's products.

(2) Indicate the resources the partner organization will be providing to support the intern's work at their premises. Include information about (1) space, (2) resources, and (3) expertise that will be provided by the organization to the intern. For **Accelerate Entrepreneur** applicants, please indicate the resources the pre-approved incubator will provide, including information about space, resources, and expertise.

I will be working in a hybrid work environment but will be spending most of my time in the company's Toronto office. I will be assigned a specific desk in the office and will be provided with the necessary hardware to execute my tasks. I will also have access to Kindred's robotic systems as I will need to test and evaluate directly on their products.

2.5. Relevance to the partner organization and to Canada:

Describe (1) the partner's proposed role in the project, (2) how the partner will benefit from participating, and (3) how the Canadian community will benefit from this research.

The partner will provide me with the necessary guidance and access to the hardware to ensure the successful completion of my project. Upon completion, the MVP is expected to improve the performance of Kindred's robotic systems. Designing fast, efficient and reliable robotic systems would pave the way for next-generation consumer robots ultimately resulting in an improved quality of life for the Canadian people and the world.

2.6. Indigenous community involvement or impact (if applicable):

Internships that involve or impact Indigenous communities must comply with the Mitacs Indigenous Research Policy. Please provide information on i) Indigenous community support for the project, and their role in shaping its objectives & approach, ii) plans for Indigenous community access, use, and governance of resulting knowledge / data, and iii) the team's background in Indigenous research, including any planned training / mentorship the intern(s) will receive to address deficits in experience.

You may also submit 1-2 letter(s) of support from Indigenous Elders who are members of the partner community / communities and possess the authority to speak on community interests.

2.7. Relationship (if any) to past/other Mitacs projects:

Describe whether or not the current project is related AND provide specifics about the relationship (e.g., not related because it refers to a different research area OR if related: provide information about what has been achieved in past projects and how the current application complements other submissions). Please include the project IT# for the previous or current project, which can be found on your Award Letter.

2.8. References:

Please cite academic references listed in this proposal.

[1] Gilbert, E. G., Johnson, D. W., & Keerthi, S. S. (1988). A fast procedure for computing the distance between complex objects in three-dimensional space. IEEE Journal on Robotics and Automation, 4(2), 193-203.

[2] Ericson, C. (2004). Real-time collision detection. Crc Press.

[3] Le Grand, S. (2007). Broad-phase collision detection with CUDA. GPU gems, 3, 697-722.

[4] Lauterbach, C., Garland, M., Sengupta, S., Luebke, D., & Manocha, D. (2009, April). Fast BVH construction on GPUs. In Computer Graphics Forum (Vol. 28, No. 2, pp. 375-384). Oxford, UK: Blackwell Publishing Ltd.

[5] Lauterbach, C., Mo, Q., & Manocha, D. (2010, May). gProximity: hierarchical GPU-based operations for collision and distance queries. In Computer Graphics Forum (Vol. 29, No. 2, pp. 419-428). Oxford, UK: Blackwell Publishing Ltd.

[6] Pan, J., & Manocha, D. (2012). GPU-based parallel collision detection for fast motion planning. The International Journal of Robotics Research, 31(2), 187-200.

3. Declarations

3.1 Will the intern conduct any of the proposed research activities outside of the academic institution or partner premises?

☐ Yes ☒ No

If yes, please describe:

a. the location
b. the nature of the activities
c. potential impact(s) or consequences on the environment, if any
d. potential risk(s) to the intern's safety, if any
e. authorizations, permits, or licenses required to undertake the activities, if any

Please note: Mitacs may request a copy of any authorizations, permits or licenses to ensure compliance.

3.2 a. Does the proposed research involve the following?

(i) Human participants whose data, or responses to interventions, stimuli, or questions by the researcher, are relevant to answering the research question?

☐ Yes ☒ No

(ii) Secondary use of human data or health information (even if anonymized)?

☐ Yes ☒ No

b. Does the proposed research involve the following?

(i) Human biological materials, as well as human embryos, fetuses, fetal tissue, reproductive materials, and stem cells? This applies to materials derived from living and deceased individuals

☐ Yes ☒ No

(ii) Secondary use of biological materials (even if anonymized)?

☐ Yes ☒ No

If Yes was checked for any of the questions above, applicants must contact the ethics offices at all participating academic institutions to determine whether ethics clearance is required. This includes primary/secondary use of human data/biological materials owned by the partner.

Please note: Mitacs may request a copy of any authorizations, permits or licenses to ensure compliance.

3.3 Will the proposed research require the use of laboratory animals, and/or potentially impact the well-being of wild/domesticated animals?

☐ Yes ☒ No

If yes, applicants must contact the animal care committees at all participating academic institutions to determine whether any certifications/authorizations are required.

Please note: Mitacs may request a copy of any authorizations, permits or licenses to ensure compliance.

3.4 Will the proposed research require the interns to handle or be exposed to biohazards?

☐ Yes ☒ No

If yes, please check all that apply:

☐ Biohazards (e.g., viruses, bacteria, fungi, parasites, toxins, prions, zoonotic pathogens, recombinant DNA, genetically modified organisms, viral vectors, synthetic organisms, cell lines/cultures)

☐ Radioactive materials

☐ Restricted substances (e.g., cannabis)

☐ Other:

If one or more options were checked, any necessary documentation must be obtained in accordance with all participating academic institutions' policies and maintained throughout the duration of the research project.

Please note: Mitacs may request a copy of any authorizations, permits or licenses to ensure compliance.

3.5 Have any academic supervisors declared a Conflict of Interest (COI)* as part of this application?

☐ Yes ☒ No

If yes, please attach the appropriate documentation outlined in section 4.1.1

3.6 Have any interns declared a Conflict of Interest (COI)* as part of this application?

☐ Yes ☒ No

If yes, please attach the appropriate documentation outlined in section 4.3.2

3.7 Does the proposed research involve the following? Please answer all questions below

(i) A partner organization located outside Canada?

☐ Yes ☒ No

(ii) A partner organization that is a Canadian subsidiary or branch office of an organization headquartered outside Canada?

☒ Yes ☐ No

(iii) A collaborator from an organization (academic, industrial, government, or non-profit) located outside Canada?

☐ Yes ☒ No

If Yes was checked for any of the questions above, please attach Appendix B: International Collaboration Form.

4. Participants

If your project involves international collaboration, please complete Appendix B.

4.1. Lead academic supervisor in Canada:

Name:	Prof. Nandita Vijaykumar
Academic institution:	University of Toronto
Department or Faculty:	Department of Computer Science
Phone:	416-978-6025
Permanent email:	nandita@cs.toronto.edu
Alternative email:	
OPTIONAL Please include any additional administrative personnel to be copied on project outcome and award letters.	
Name:	
Email:	

4.1.1. Academic supervisor conflict of interest declaration:

a. Do you have any current or previous relationships, ownership, influence, positions (whether salaried or not) or circumstances with the partner organization or other program participants that could contribute to a conflict of interest, or to the appearance of a conflict of interest? Please refer to the Mitacs Conflict of Interest Policy.

☐ Yes
☒ No

b. Have you disclosed a conflict of interest pertaining to this Mitacs application to your academic institution in accordance with your academic institution's conflict of interest policies?

☐ Yes
☐ No

If yes to either of the above, please provide a copy of your approved academic institution's conflict of interest declaration, or Mitacs's Academic Institution Acknowledgement form, with your application. The documents must contain confirmation that your academic institution is aware of the potential conflict of interest, describe the nature of the conflict, and detail any measures in place to manage the conflict.

Generally, Mitacs accepts the mitigation measures put in place by your academic institution. If your academic institution's mitigation measures include the appointment of an independent administrator, please also complete the Independent Administrator profile for Accelerate.

In some instances, Mitacs may require additional mitigation measures to what was put in place by your academic institution. If required, Mitacs will communicate this to you alongside the outcome letter for your application or through your Mitacs Business Development representative.

For any additional academic co-supervisors in Canada, copy and paste Section 4.1. and 4.1.1 below:

4.2. Partner organization in Canada:

Legal name (REQUIRED):	Kindred Systems II Inc.
Operating name (if different):	Kindred AI
Contact name:	Kevin George

Position:	Engineering Manager	
Department:	Machine Learning Engineering	
Address:	325 Front Street. Suite 100	
City, province/territory, postal code:	Toronto, Ontario, M5V 2Y1	
Phone:	844-344-2088	
Email:	kevin@kindred.ai	
Website:	https://www.kindred.ai/	
Partner size (number of employees):	100-499	
Legal status:	For Profit Canadian Corporation	
If not-for-profit Canadian corporation	Select NFP Type	
NAICS code (First three digits)*:	541	
* Click here for a list of North American Industry Classification System codes.		
Is this the **first time** the partner has collaborated with the academic institution? :	No	

For any additional partner organization in Canada copy and paste Section 4.2. below:

Please note that the financial contribution of organizations with permanent establishments in Canada may be subject to any applicable Goods and Services Tax (GST), Harmonized Sales Tax (HST) and/or Quebec Sales Tax (QST) (collectively VAT).

4.2.1 Invoicing partner contact

Partner contributions must be received by Mitacs BEFORE any funds are awarded to the academic institution. **Costs can only be incurred after research approval of the proposal** and the **receipt** of the partner funds at Mitacs**.**

a. Please describe any applicable **invoicing requirements** (vendor setup, PO, tax exemption, etc.):

Billing contact name:	Cynthia Perla
Billing phone number:	(844) 344-2088 x708
Billing email address:	cynthia@kindred.ai
Accounts payable email address:	kindred-invoices@ocado.com
Partner organization wishes to be invoiced by term, annually, or in one payment:	By term
Is there a P.O. required?	☐ Yes (please provide the PO number): ☒ No
Does your organization hold tax exemption status?	☐ Yes* ☒ No ***If yes,** please attach proof of tax exemption with your application
Other invoicing instructions: (additional billing contact names, email addresses, etc.)	please do not mail invoices please use the email address provided 721 Brannan Street San Francisco CA 94103

b. Invoicing partner address:

Address:	Invoicing address is different than Section 4.2 or Appendix B (Section 4.2)
If invoicing address different than Section 4.2 or Appendix B (Section 4.2), please fill out the following	
Legal name:	Kindred Systems II Inc.
Address:	721 Brannan Street
City, country, postal code:	San Francisco, CA, 94103

c. Have these funds been leveraged against other federal or provincial programs?
☐ Yes ☒ No

If yes, please provide details:

4.2.2 Partner funds at academic institution. *IF APPLICABLE*

To be completed only if partner funds were sent as an exception to the academic institution**. If no,** please proceed to section 4.3.

a. Is there a **research agreement** in place with the academic institution that governs the use of these partner funds?

☐ Yes ☐ No

If yes, please speak with your Business Development representative. You may need to fill out the *Cash Flow Statement and Certificate* document and submit that document with your completed application.

If no, please complete the following:

(i) ORS/UILO or equivalent agrees to send these funds to Mitacs?

☐ Yes ☐ No

If yes, please provide:

Academic institution account number:	

(ii) The partner agrees by signing this application that the funds can be forwarded?

☐ Yes ☐ No

If yes, please provide:

Name of the consenting partner representative:	

(iii) Is the GST or HST, and QST (if applicable) to be included with the invoice to the academic institution?

☐ Yes ☐ No

If no, tax(es) will be invoiced directly to the partner organization.

b. Invoicing academic institution contact to receive Mitacs invoice:

Name:	
Department:	
Email:	

4.3. Intern(s) identified:

4.3.1. Intern #1 information

Name:	Sumant Bagri	
Full-time diploma or degree program at the start of the internship:	Master's	If Other, please specify diploma or degree program:
If applying for a **College, Undergrad, Master's, PhD, or Other** internship:	Indicate expected month/year of graduation:	12/2023
If applying for a **Recent Graduate** internship:	Select most recent diploma or degree obtained:	Select most recent diploma or degree
	Indicate month/year diploma or degree obtained:	MM/YYYY
If applying for a **PDF** internship:	Indicate month/year PhD obtained:	MM/YYYY
Academic institution during internship:	University of Toronto	
Department or Faculty:	Computer Science	
Country:	Canada	
Phone:	437-322-4187	
Permanent email:	sbagri@cs.toronto.edu	
Alternative email:		
Citizenship:	**Foreign**	If foreign, please indicate citizenship: Indian
For internships with international travel only (please complete Appendix B in addition to the full application):		
Will this intern conduct any internship units at a partner organization outside of Canada?	No	
OPTIONAL: If known, please indicate anticipated **travel** dates	Start date: DD/MM/YYYY End date: DD/MM/YYYY	

Mitacs will invite you to complete a self-identification data collection form by email. Collection of this data is a mandatory requirement for our funders, which helps to secure continuous funding for our programs.

4.3.2. Conflict of interest

Do you have any current or previous relationships, ownership, influence, positions (whether salaried or not) or circumstances with the partner organization or other program participants that could contribute to a conflict of interest, or to the appearance of a conflict of interest? Please refer to the Mitacs Conflict of Interest Policy.

☐ Yes
☒ No

If yes to the above, please complete the **Mitacs Intern Eligibility and Conflict of Interest Declaration Form** and send it to your Mitacs Business Development representative for review **BEFORE** submitting your application. If you are applying for **Accelerate Entrepreneur**, please complete the **Mitacs Accelerate Entrepreneur COI Declaration Form**

4.3.3. International intern affiliations *IF APPLICABLE*

To be completed only if intern's home academic institution is based outside of Canada.

Does the intern have any current or past affiliations with military or government organizations?

☐ Yes
☐ No

If yes, please describe:

For any additional interns copy and paste Section 4.3. below:

4.4. Intern(s) to be determined (TBD):

TBD#1

Full-time diploma or degree program during the internship:	Select diploma or degree program
Academic institution:	
Department or Faculty:	
For internships with international travel only (please complete Appendix B in addition to the full application):	
Will this intern conduct any internship units at a partner organization outside of Canada?	Select yes/no
OPTIONAL: If known, please indicate anticipated **travel** dates	Start date: DD/MM/YYYY End date: DD/MM/YYYY

For any additional TBD interns, copy and paste Section 4.4. below:

5. Budget and invoicing

All Accelerate projects are required to include a complete Accelerate budget and the invoicing schedule on the Excel budget spreadsheet template must be confirmed. Please refer to the **Accelerate Guide: Writing your proposal** for assistance.

6. Suggested reviewers

6.1. Reviewer's comments. Please select ONE of the following:

☐ We consent to receive reviewer's comments in either official language (French or English).

☒ We request to only receive reviewer's comments in the language in which this proposal is submitted.

6.2. Please provide the names and contact information of at least **SIX (6) arm's length** reviewers.

An arm's length reviewer must:

- Be a recognized expert in the research topics and/or technical aspects covered by the proposal
- NOT be from the same academic institution as the intern(s) or the academic supervisor(s); and
- NOT have had any collaboration with the intern(s) or the academic supervisor(s) or the partner(s) during the past five (5) years or planned for the near future

Do not include more than two (2) professors or instructors from one academic institution

Please note that suggested reviewers who qualify as arm's length are required for the review of your application.

Reviewer 1:

Name:	
Academic institution:	
Department:	
Email:	

Reviewer 2:

Name:	
Academic institution:	
Department:	
Email:	

Reviewer 3:

Name:	
Academic institution:	
Department:	
Email:	

Reviewer 4:

Name:	
Academic institution:	
Department:	
Email:	

Reviewer 5:

Name:	
Academic institution:	
Department:	
Email:	

Reviewer 6:

Name:	
Academic institution:	
Department:	
Email:	

Potential conflict of interest. ***OPTIONAL***

Please list reviewers you would prefer Mitacs not to contact.

Name:	
Academic institution / Research group:	

Name:	
Academic institution / Research group:	

7. Mitacs Accelerate Memorandum

The participants listed below confirm that the information presented accurately reflects their intention to apply to the Mitacs Accelerate program. The participants have also agreed to set in place an internship based upon the attached proposal. The participants acknowledge that they have read, understood and agreed to abide by and uphold the project responsibilities applicable to each of them, available for reference at http://www.mitacs.ca/en/programs/accelerate/project-responsibilities, which include and are not limited to the following: It is understood that the partner organization contribution shall be provided to Mitacs Inc. in Canadian dollars prior to commencement of the internship; in the event that the sponsor organization funds are at the academic institution, the academic institution shall forward these funds to Mitacs. Upon research approval and the receipt of the partner funds at Mitacs, Mitacs shall forward the funds to the Canadian academic institution as a research grant to the Canadian supervising professor, and the internship stipend/salary will be paid to the student by the academic institution from the grant. Costs associated with this proposal as outlined in the budget can only be incurred after research approval of the proposal and the receipt of the partner funds at Mitacs.

Mitacs is unable to assume liability for any losses including—but not limited to—accidents, illness, travel, or other losses that may occur during the internship period. All undersigned parties agree that they are responsible for ensuring that they have appropriate insurance and meet any institutional policies regarding health, safety, and travel preparation requirements. All parties also agree that the intern will provide Mitacs with a final report and that all participants will complete an exit survey within one month of internship completion.

For projects involving international travel: In acknowledging that international exposure can greatly enhance an intern's learning and experience, Mitacs will approve international travel provided that participation does not impact the safety and security of the intern and meets the policies outlined by the home academic institution. By signing this memorandum, you are acknowledging that the home academic institution agrees to assist the intern in meeting all academic institution requirements pertaining to research abroad and that the intern understands that they are responsible for obtaining insurance appropriate for the travel destination. Participants in projects involving international travel acknowledge that additional project responsibilities apply to each of them, available for reference at https://www.mitacs.ca/en/programs/accelerate/mitacs-accelerate-international. Participants in projects involving international travel also acknowledge that the internship cannot begin, and funds cannot be released until Mitacs receives the signed International Pre-Departure Form and Code of Conduct and Ethics forms.

All parties involved with Mitacs Accelerate are bound by the standard intellectual property (IP) terms of the academic institution where the intern is enrolled; except where intellectual property is covered by separate agreements to which the academic institution(s) and the partner organization are parties and that are active during the dates of the internship. By signing this memorandum, if you have separate agreements covering IP between you and the academic institution, you are acknowledging that you are bound by their specific terms and conditions. Otherwise, if you don't have separate agreements, you are bound by the standard intellectual property terms of the academic institution, and by signing this memorandum you agree to the terms of the academic institution where the intern is enrolled. Institution-specific IP policies regarding Accelerate internships can be found at https://www.mitacs.ca/en/programs/accelerate/faq.

The participants also agree that Mitacs will post the title of the project, the public project overview, the name of the partner(s) organization(s), the name of the intern(s), the name of the supervisor(s) and the involved academic institution on www.mitacs.ca/en/projects and may be used by Mitacs to publicize Mitacs Accelerate. Mitacs Privacy Policy can be found at www.mitacs.ca/en/privacy-policy.

Internship participants (intern, academic supervisor, and partner) further agree to the following addendum(s):

Mitacs does not require, inspect, or enforce any additional terms as outlined by participants in the above addendum.

7.1. Title of the project:

Hardware accelerated collision checking for robotics

7.2. Public project overview:

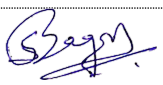
Using simplified language understandable to a layperson, provide a general, one-paragraph description of the proposed research project to be undertaken by the intern(s) as well as the expected benefit to the partner organization. **(100-150 words)**

The ability to quickly check if robot poses are not in collision with environment geometry is critical for robot applications that rely on forward kinematics, inverse kinematics, and path planning. It has been shown that during path planning 99% of the time is spent performing collision checks between the robot & its environment. Improving collision checking speed can have a dramatic impact on the feasibility of planning in real-time and the quality of the plans produced. The objective of this project is to prototype a collision checking library that can utilize the faster vector operations of a specialized compute like GPU

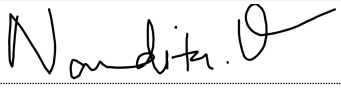
7.3. Participant signatures:

Please sign, scan, and save in PDF format. Typed signatures will not be accepted. E-signature or signature images are preferred.

7.3.1. Intern:

Name:	Sumant Bagri	
Department:	Department of Computer Science	
Academic institution:	University of Toronto	
	For interns participating in international travel: The intern acknowledges that additional project responsibilities found at www.mitacs.ca/en/programs/accelerate/mitacs-accelerate-international apply to Accelerate International travel (as outlined in the Memorandum above) and agrees to abide by these additional program rules. The intern also acknowledges that they are aware of and agree to any IP agreements related to this project.	
	For interns participating in the Indigenous Pathways program: [☐] The intern self-identifies as an Indigenous person.	
Signature:		Date: March 24, 2023

7.3.2. Academic supervisor in Canada:

Name:	Nandita Vijaykumar	
Department:	Department of Computer Science	
Academic institution:	University of Toronto	
Signature:		Date: March 21, 2023

7.3.3. Academic supervisor abroad (if applicable):

Name:		
Department:		
Academic institution:		
Signature:		Date:

7.3.4. Partner organization in Canada (if applicable):

Name:	Hashruti Patel
Department:	Finance

Title/position:	Controller	
Legal name of organization:	Kindred Systems II Inc.	
Total financial commitment:	$15,000	
	The partner organization commits to the funding contribution specified directly above and the payment schedules outlined in the attached *Accelerate Budget and Invoicing* schedule. These are key conditions of the application and by signing this proposal below, the partner organization agrees to these conditions. Please note that the financial contribution of organizations with permanent establishments in Canada may be subject to any applicable Goods and Services Tax (GST), Harmonized Sales Tax (HST) and/or Quebec Sales Tax (QST) (collectively VAT).	
	For partner organizations participating in the Indigenous Pathways program, check any that apply: [☐] The partner organization is a for-profit organization with self-identifying Indigenous persons who hold 50% or greater ownership shares [☐] The partner organization is a not-for-profit organization with board membership consisting of 50% or greater self-identifying Indigenous persons [☐] The partner organization is a not-for-profit organization whose core mandate includes Indigenous community impact or serving Indigenous communities	
Signature:	Hashruti Patel	Date: March 22, 2023

7.3.5. Partner organization abroad (if applicable):

Name:		
Department:		
Title/position:		
Legal name of organization:		
Financial commitment:	$	
	The partner organization commits to the funding contribution specified directly above and the payment schedules outlined in the attached *Accelerate Budget and Invoicing* schedule. These are key conditions of the application and by signing this proposal below, the partner organization agrees to these conditions. **Please note that the financial contribution of organizations may be subject to applicable taxes.**	
Signature:		Date:

7.3.6. Office of Research Services representative or equivalent:

By signing, the ORS or equivalent is confirming that academic supervisor(s) can hold Tri-Agency funds.

Name:		
Title/position:		
Academic institution:		
Signature:		Date:

For any additional participants include corresponding details and signature line below:

Appendix A – Accelerate Intern Consent Form

USE AND DISCLOSURE OF PERSONAL INFORMATION PROVIDED TO MITACS

1. All personal information collected is subject to privacy legislation and Mitacs Privacy Policy for Program Participants. For a description of Mitacs's commitment to protecting the personal information provided by program applicants, please see http://www.mitacs.ca/en/privacy-policy.
2. All the information supplied in this application will be made available to Mitacs staff responsible for managing the application, for activities including identifying appropriate peer reviewers, administering and monitoring awards, compiling statistics, and evaluating the program.
3. Information supplied in this application will be made available to internal and/or external reviewers, being composed of experts recruited from the academic, public, and private sectors. All reviewers are required to commit to keep the application information confidential.
4. Contact information in this application may be used by Mitacs staff to contact you in the future for:
   a. Invitations to be profiled in stories or news items, to speak at or attend events, to provide a spotlight story and/or blog post
   b. Communications about opportunities for Mitacs alumni; and
   c. Research surveys for Mitacs alumni

   You will have the opportunity to unsubscribe from emails sent to you, once all commitments regarding the internship that is the subject of this application are complete.
5. Your name, academic institution and department, and the title of your project may be provided to the federal, provincial/territorial, and academic institution funders of the Accelerate program, to:
   a. Enable Mitacs to report on funding contract commitments; and
   b. Allow the funders to evaluate the program.

   Additional information, such as passport numbers and dates of birth, may be provided to the international funders of the program (if applicable), for adjudication and reporting purposes.
6. Your name, contact information, and other personal information as required may be provided to the academic institution(s) participating in the internship to enable the academic institution(s) to manage the award, to sign off on the pre-departure form (if applicable), and for reporting purposes.

I, the undersigned, do hereby give CONSENT to the use and disclosure of the information contained in my application for the purposes described above.

_____Sumant Bagri_____	_____	24/03/2023
Intern name	Signature	Date

Appendix B –
Mitacs Accelerate:
International Collaboration Form

If the internship involves international collaboration, please complete the following:

B 1. Intellectual property

B 1.1 Will the proposed research make use of intellectual property that was developed at the participating Canadian academic institution?

☒ Yes
☐ No

If yes, please describe: The collision checking library will be integrated with the software and hardware stack at Kindred AI. All the research activities in the proposed application will be carried out in Canada only.

B.1.2 Is there an intellectual property agreement between the participating Canadian academic institution(s) and the partner organization(s) that applies to the proposed research project?

☐ Yes
☒ No
☐ In development

If Yes or In development, please attach a copy of the signed or draft intellectual property agreement.

If no, please explain: IP resulting from collaboration with MScAC, UofT Program will be owned by Kindred AI, as per the MScAC program. All the research activities in the proposed application will be carried out in Canada only.

B 2. Additional information on partner interaction

B 2.1 Duration of internship in Canada and abroad

Interaction % on-site at partner location in Canada	75 %
Interaction % on-site at partner location abroad	_____ %
Interaction % at academic institution in Canada	25 %
Interaction % at academic institution abroad	_____%
TOTAL (must equal 100%)	100%

B 2.2 Do any interns expect to spend more than twelve (12) consecutive months outside of their home country?

☐ Yes
☒ No

If yes, Mitacs may request additional information.

B 2.3 Does this project create new international collaborations?

☐ Yes
☒ No

If no, please briefly describe the nature of the existing international collaboration. Include a summary of the collaboration, duration of the collaboration, and any past exchange of personnel, etc.

Intern will be guided by Kevin George, who is based in Canada. There will be no contact with offices outside of Canada. The time spent on site will only be at 325 Front Street throughout the project. Intern will also be working closely with and receive support from the Kindred AI Canada team

B.3. Previous collaborations

B 3.1 Have any of the project participants engaged in a previous collaboration with each other?

☐ Yes
☒ No

If yes, please specify which participants have engaged in a previous collaboration and describe. Include a summary of the collaboration, duration of the collaboration, and any past exchange of personnel, etc.

B 4. Additional participant information:

B 4.1 Academic supervisor abroad (if applicable):

Name:	
Academic institution:	
Department:	
Address (at academic institution):	
City, country:	
Postal code:	
Phone:	
Permanent email:	
Alternative email:	

B 4.1.1 Conflict of interest

Do you have any current or previous relationships, ownership, influence, positions (whether salaried or not) or circumstances with the partner organization or other program participants that could contribute to a conflict of interest, or to the appearance of a conflict of interest? Please refer to the Mitacs Conflict of Interest Policy.

☐ Yes
☒ No

B.4.1.2 Affiliations

Do you have any current or past affiliations with military or government organizations?

☐ Yes
☒ No

If yes, please describe:

B 4.2 Partner organization abroad (if applicable):

Legal name:	
Operating name (if different):	
Contact name:	
Position:	
Department:	

Address:			
City, postal code:			
Country:			
Does the organization have a permanent establishment in Canada?	Select yes/no		
Phone:			
Email:			
Website:			
Partner size (number of employees):	Select No. employees		
Legal status:	Select Legal Status		
NAICS Code (First three digits)*:			
* Click here for a list of North American Industry Classification System codes.			
Is this the **first time** the partner has collaborated with the academic institution?	Select yes/no		

Appendix C – Drop-down list options

Please delete if not applicable

Please refer to the drop-down list of the section and type the corresponding answer in the space provided.

1.5. Academic discipline:

- Business
- Computer science
- Earth sciences
- Engineering
- Life sciences
- Mathematical
- Social sciences, Arts & Humanities
- Physical sciences

1.6. Project priority sectors:

- Advanced manufacturing
- Aerospace
- Agriculture and food
- Aquaculture and fishing
- Artificial intelligence
- Automotive
- Biomanufacturing
- Biotechnology
- Cannabis
- Clean technology
- Commercial services
- Construction
- COVID-19-related research and solutions
- Cybersecurity
- Education
- Energy and utilities
- Entertainment and media
- Environmental science and technology
- Finance and insurance
- Forestry
- Green/alternative energy
- Health and related sciences and technology
- Indigenous innovation
- Information and communications technology
- Life sciences (not health)
- Manufacturing and construction
- Mining
- Nanotechnology
- Natural gas
- Natural resources
- New and digital media
- Oceanography
- Oil and gas
- Pharmaceuticals
- Public service, policy, and governance
- Quantum science
- Social innovation
- Sustainability and the environment
- Technology
- Tourism
- Transportation (excluding aerospace)
- Water
- Other (please describe)

1.7. List of participants:

Partner legal status:

- For-profit corporation
- Crown corporation
- Not-for-profit Canadian corporation
- Hospital
- Municipality

4.2. Partner organization in Canada:

Partner size (No. of employees):

- 1 to 49
- 50 to 99
- 100 to 499
- 500 to 999
- 1,000 and higher

Legal status:

- For-profit Canadian corporation
- Crown corporation
- Not-for-profit Canadian corporation
- Hospital
- Municipality

If NFP:

- Charitable organization
- Economic development organization
- Health organization
- Industry association
- Social welfare organization
- Other

First-time collaboration with academic institution?

- yes
- no

4.2.1 Invoicing partner contact

Partner organization wishes to be invoiced by internship unit or annually:
- By term
- Annually
- One payment

Invoicing partner address:
- Address same as filled in Section 4.2
- Address same as filled in Appendix B (Section 4.2)
- Invoicing address is different than Section 4.2 or Appendix B (Section 4.2)

4.3 Intern(s) identified:

4.3.1. Intern information:

Full-time diploma or degree program at the start of the internship
- College
- Undergrad
- Master's
- PhD
- PDF
- Recent graduate
- Other

If applying for a recent graduate internship, select the most recent diploma or degree obtained
- Recent grad - College
- Recent grad - Undergrad
- Recent grad - Master's
- Recent grad - PhD

Citizenship:
- Canadian
- Canadian permanent residence
- Foreign

Will this intern conduct any internship units at a partner organization outside Canada?
- yes
- no

4.4. TBD

Full-time diploma or degree program during the internship
- College
- Undergrad
- Master's
- PhD
- PDF

Will this intern conduct any internship units at a partner organization outside their home country?
- yes
- no

B 4.2. Partner organization abroad (if applicable):

Does the organization have a permanent establishment in Canada?
- yes
- no

Partner size (No. of employees):
- 1 to 49
- 50 to 99
- 100 to 499

- 500 to 999
- 1,000 or higher

Legal status:

- For-profit corporation
- Crown corporation

First-time collaboration with academic institution?

- yes
- no