## Project Interim Progress Report(Rapport d’avancement de project intérimaire)February 1, 2016 – June 30, 2017Please submit by April 28, 2017(Attn: Joanne O’Connor management@nserc-canrimt.org)

## Instructions

*This progress report, updated milestones**and the Form 300 are required as a condition of research funding support from the sponsors of the NSERC CANRIMT.* ***Please report for activity in the current reporting period only.***

**SUMMARY**

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| **THEME :** Virtual Model-Assisted Machining Monitoring and Control | **Leader/ Chef:** *R. Mayer / Ecole Polytechnique* |
| **PROJECT II.A.9:** High-Speed Computation of Time-Optimal Toolpaths and Feedrate Profiles | **Leader/ Chef:** *K. Erkorkmaz**U. Waterloo*  |
| **PROJECT DURATION/DURÉE DU PROJET :**  |
| **STATUS/STATUT:** *(****Milestones*** *to be updated by each Project Leader)* |
|  **Ahead of Schedule** |  | **On Schedule** |  |  **Delayed** | **✓** | **Cancelled** |  |

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| **PROJECT DESCRIPTION/ DESCRIPTION DU PROJECT** (*Brief description in point form, including role of project in Theme.)* |
| * This project targets the development of computationally efficient and robust real-time algorithms to generate time-optimal feedrate profiles. These profiles will be used in contour machining of complex spline (smooth and curved) toolpaths.
* This project supports advanced process planning and motion optimization research for machine tools within Theme II. It plays a complementary role to the laser drilling trajectory optimization project (II.A.8). The end results contribute to achieving higher levels of distributed intelligence and better utilization of process and multi-axis machine tool capabilities, as targeted within CANRIMT.
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| **PROJECT OBJECTIVES & METHODOLOGY/ OBJECTIFS DU PROJET & MÉTHODOLOGIE** *(Include alignment with Network objectives.)* |
| *Upon consultation with industry partner CADlink, it was decided to swap the order of this project with Project II.A.10 (on precision motion controls), in order to address the most urgent technology development needs felt by the industry partner. Hence, in updated timing, this project (II.A.9) will now start in 2018Q3. II.A.10 starts in 2016Q3.* Objectives: New generation of robust, computationally efficient, and real-time feed optimization and spline interpolation algorithms will be developed.Methodology: A new generation of computationally efficient and fast algorithms for solving time-optimal trajectory profiles will be researched. One approach will be to extend the forward looking algorithm, which has been implemented inside industrial partner CADlink’s CNC, from single dimensional bisection of feed rate to multidimensional bisection of feed rate, tangential acceleration, and jerk during intermediate solution steps. This is expected to produce trajectories with even shorter cycle times. Another method to be researched is re-casting the actuator jerk-constrained nonlinear optimization problem into a linearized form, by substituting the jerk constraint with a linearized approximation, named ‘pseudo-jerk’. This substitution turns the optimization into a convex Linear Programming (LP) problem, which can be efficiently solved using fast and reliable LP solvers. Partial solution methods, such as windowing, will also be investigated for handling indefinitely long tool paths. In tool path planning, optimal connection methods between B-splines, circular arcs, and linear segments will be investigated. Based on actuator kinematic limits, template optimal trajectories will be solved as polynomials of time. Afterwards, their geometric projection will be approximated with key descriptors, and the feed optimization algorithm will be used to generate the best possible timing during real-time implementation. Comparing trajectories synthesized using the different methods will follow. As each algorithm is developed, it will be integrated inside CADlink’s CNC, and also become available inside UBC’s Virtual CNC.* This project aligns closely with CANRIMT’s objective of developing advanced tool positioning algorithms that enhance productivity and quality outcomes.
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| **1. RESEARCH TEAM/ ÉQUIPE DE RECHERCHE** *(Summary for the current reporting period)* |

**1a: Research Personnel (Supervisors, Co-Supervisors, Collaborators)/
Personnel de recherche**

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| *Name, given name/Nom., prénom* | *Organization/Organisation* | *Sup./Co-Sup./* *Collaborator* | *E-mail/Courriel* | *Phone No./Téléphone* |
| Erkorkmaz, Kaan | Waterloo | Supervisor | kaane@uwaterloo.ca | 519 888 4567 x32541 |
| Reynen, Gordon  | CADlink Tech. Corporation | Collaborator | gordr@cadlink.com | 613 247 0850x214 |

**1b: Students, Postdoctoral Fellows, Research Assist./
Assoc./Eng., Technical/Professional, Guests** *(from outside Province; from outside Canada)***/
Étudiants, Boursier de recherches postdoctorales, assistants, techniciens et invites** *(invite hors Province; hors Canada)*

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| *Name, given name/Nom., prénom* | *Position* | *Organization/Organisation* | *Name/Nom.(S) or /ou (C)\** | *Start/Début* | *End/ Fin* | *CANRIMT Salary/Moincl ben.* | *Extern.fundingamount* | *Externfundingsource* |
| TBD | MASc | U.Waterloo | Erkorkmaz (S) |  |  |  |  |  |

***\*(S) – Supervisor , (C) – Co-Supervisor***

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|  **TOTAL #** | **BASc** | **MASc/** **M.Eng.** | **Ph.D.** | **PDF** | **Res. Asst.** | **Res. Assoc.** | **Res. Eng.** | **Tech./ Prof.** | **Guests/outside Province** | **Guests/outside Canada** |
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**1c: Partners & Contributions/
Partenaires et Contributions**

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| *Organization /Organisation* | *Acronym/Acronyme* | *Contact*  | *Cash/Espèce* | *In-Kind/ Nature* | *Overhead/Frais généraux* | *Total* |
| CADlink Tech. Copr. | CADlink | Gordon Reynen | $0 | $0 | $0 | $0 |
| **2. RESEARCH PLAN FOR THE CURRENT PERIOD/PLAN DE RECHERCHE POUR LA PÉRIOD ACTUELLE** *(Please list both the technical objectives, methodologies and milestones as stated in the previous report.)* |
| **This project will start in 2018Q3.**Milestone 1 - Literature reviewMilestone 2 - Extension of forward looking algorithm to multi-dimensional bisection for shorter cycle timeMilestone 3 - Pseudo-jerk based linear programming with partial solution and windowing for long toolpaths |

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| **3. ALIGNMENT OF RESEARCH PROJECT WITH NETWORK OBJECTIVES/ALIGNEMENT DU PROJET DE RECHERCHE AVEC LES OBJECTIFS DU RÉSEAU***( Please comment on the alignment of the research project with the overall Network objectives.)* |
| The research project aligns well with the network objectives. It falls squarely within establishing advanced trajectory planning techniques for multi-axis production machines, in order to help boost productivity and quality outcomes of manufacturing operations.  |

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| **4. PROBLEMS and RESOLUTIONS/ PROBLEMES ET SOLUTIONS PROPOSÉES***( Please summarize any problems arising during the current reporting period and their resolution or plans for resolution.)* |
| *Problem/ Problème:** No problems encountered so far.

*Resolution / Résolution:** N/A.
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| **5. RESEARCH PROGRESS and RESULTS/ PROGRÈS DE LA RECHERCHE et RESULTATS:***(Summarize progress and results below.)* |

**5a: MILESTONES/ÉTAPES**
*Summarize progress on milestones – including % completed – as outlined in the Research Plan for the current reporting period and any modifications since the last reporting period.* *(Milestones document also to be updated for each project.)*

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| **MILESTONE/ ÉTAPE:** |
| **Progress:****Modifications:** |
| **% Completed/ Rempli:** |  |

**5b: PUBLICATIONS and PRESENTATIONS / PUBLICATIONS ET PRESENTATIONS**

*Please list all publications directly arising from Network-funded research during the current period. Do not include abstracts.*

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| ***A: REFEREED CONTRIBUTIONS - ARTICLES****Include articles in refereed publications – please specify whether the article has been submitted (S), accepted (A) or published (P).* |
| Last Name, Initial | *Year* | *Title, Journal, Volume* | *Status* |
|  |  |  |  |
| ***B: REFEREED CONTRIBUTIONS - OTHER****Include papers in refereed conference proceedings, letters, notes, communications, review articles, monographs, books, book chapters and government publications.* |
| Last Name, Initial | *Year* | *Description* | *Status* |
|  |  | Conference Title, Location and Date (Status: Invited, Not invited) |  |
|  |  | Journal/Book/Publication Title (Status: S-submitted; A-accepted; P-published) |  |
| ***C: NON-REFEREED CONTRIBUTIONS****Include papers in non-refereed conference proceedings, papers, letters and review articles.* |
| Last Name, Initial | *Year* | *Description* |
|  |  | Conference Title, Location and Date  |
|  |  | Journal/Book/Publication Title  |
| ***D: SPECIALIZED PUBLICATIONS - PRESENTATIONS****Include theses, presentations, industrial/technical reports, internal reports, discussions of abstracts and symposium records.* |
| Last Name, Initial | *Year* | *Description* |
|  |  | Thesis or Conference Title, Location and Date  |
|  |  | Journal/Book/Publication Title  |
| ***E: PUBLICATIONS – Not originally funded by NSERC CANRIMT but continuing or completed with Network funding***  |
| Last Name, Initial | *Year* | *Description/Title* ***(include start date of NSERC CANRIMT funding)*** |
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| ***F: PUBLICATIONS –Not funded by NSERC CANRIMT but related to the Network research focus***  |
| Last Name, Initial | *Year* | *Description/Title* |
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**5c: PATENTS and LICENSES/ BREVETS ET LICENSES**

*Non-disclosure agreements signed, patent applications filed, patents issued, copyrights, licenses under negotiation, licenses granted, etc.*

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| *Category* | *Owner* | *Description* |
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**5d: OTHER COMMUNICATIONS, AWARDS/ AUTRES COMMUNICATIONS, PRIX**

*Provide information on additional communications related to your work, such as awards and distinctions, news stories, interviews, public forums, press releases, etc. for the current reporting period (please provide copies or links.)*

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| *Name, given name/Nom, prénom* | *Details* | *Date* | *Link or copy attached* |
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| **6. TRAINING/ FORMATION** *(Describe the extent of cross-network and partner involvement in training for the current reporting period.)* |
| A MASc student will be recruited for this project. |

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| **7. RESEARCH PLAN FOR NEXT 6 MONTHS/ PLAN DE RECHERCHE POUR LES 6 PROCHAINS MOIS***(Describe Planned Research Activities for the next 6 month period and include any modifications made during the current reporting period.); also please list both the technical objectives and milestones.)* |
| This project has been re-scheduled to starts in 2018Q3. |

**8. OPTIONAL – Comments, Questions and/or Feedback/
OPTION – Commentaires, questions et/ou des commentaires**

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| *Include any supplemental comments or questions pertaining to the Network here.* |
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**9. NETWORK EVENTS ATTENDED or SUGGESTIONS /
ÉVÉNEMENTS RÉSEAU ONT ASSISTÉ ou SUGGESTIONS**

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| *Please list any Network-related events attended and include comments and suggestions for events which may be helpful and informative for Network members to attend in future.* |
| *Event* | *Comments/Suggestions* |
| CIRP General Assembly, Portugal (Aug 2016) |  |
| ASPE Topical Conference on Precision Motion Control Systems (Apr 2016) |  |