Natural Sciences and Engineering Research Council of Canada | Conseil de recherches en sciences naturelles et en génie du Canada

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## Form 101 - Application for a Grant

**Send to NSERC with your attachments, if applicable**

**Reference Number:** 371079020

**Applicant:** Jun Chen
McMaster

**NSERC PIN:** 327936

**Program:** Engage Grants for universities

**Application Title:** A Rate-Constrained Video Descriptor Based on the Information Bottleneck Principle

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Jun Chen

Form 101 - Application for a Grant

**Electronic Attachments:**

Contributions from Supporting Organizations - Attachment - Contributions from Supporting Organizations
Budget Justification - Justification
Relationship To Other Research Support - Relationship
Proposal - Proposal

Jun Chen

F100/Personal Data Form

**Electronic Attachments:**

Contributions - Contributions

Chris Jones

F183A/Org. Participating in RPP

**Electronic Attachments:**

Letter of Support - Letter of Support
Company Profile - Company Profile

Natural Sciences and Engineering Research Council of Canada | Conseil de recherches en sciences naturelles et en génie du Canada

# FORM 101
## Application for a Grant
## PART I

| Institutional Identifier | | | |
|---|---|---|---|
| System-ID (for NSERC use only) 371079020 | | | Date 2015/09/17 |
| Family name of applicant: Chen | Given name: Jun | Initial(s) of all given names: J | Personal identification no. (PIN): **Valid** 327936 |

| Department | Institution that will administer the grant |
|---|---|
| Electrical and Computer Engineering | McMaster |
| Language of application [X] English [ ] French | Time (in hours per month) to be devoted to the proposed research / activity: 20 |
| Type of grant applied for: Engage Grants for universities | For Strategic Projects, indicate the Target Area and the Research Topic; for Strategic Networks indicate the Target Area. |

Title of proposal
A Rate-Constrained Video Descriptor Based on the Information Bottleneck Principle

Provide a maximum of 10 key words that describe this proposal. Use commas to separate them.
data compression, video descriptor, visual analysis, informaton bottleneck

| Research subject code(s) | | Area of application code(s) | |
|---|---|---|---|
| Primary | Secondary | Primary | Secondary |
| 2718 | 2708 | 1207 | 802 |

**CERTIFICATION/REQUIREMENTS**

If this proposal involves any of the following, check the box(es) and submit the protocol to the university or college's certification committee.

Research involving : Humans [ ] Human pluripotent stem cells [ ] Animals [ ] Biohazards [ ]

Indicate if the proposed research takes place outdoors and if you answered YES to a), b) or c) – Appendix A (Form 101) must be completed

[X] NO [ ] YES

**TOTAL AMOUNT REQUESTED FROM NSERC**

| Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|
| 25,000 | 0 | 0 | 0 | 0 |

I certify that this project will involve only industry partners with whom no prior research partnership has taken place: Yes

**SIGNATURES (Refer to instructions "What do signatures mean?")**

It is agreed that the general conditions governing grants as outlined in the NSERC *Program Guide for Professors* apply to any grant made pursuant to this application and are hereby accepted by the applicant and the applicant's employing institution.

Applicant

Applicant's department, institution, tel. and fax nos., and e-mail

Electrical and Computer Engineering
McMaster
Tel.: (905) 5259140 ext. 20163
FAX: (905) 5212922
junchen@ece.mcmaster.ca

Head of department

Dean of faculty

President of institution (or representative)



The information collected on this form and appendices will be stored in the Personal Information Bank for the appropriate program.

**PROTECTED WHEN COMPLETED**

Version française disponible

Canada

| Personal identification no. (PIN) | Family name of applicant |
|---|---|
| **Valid** 327936 | Chen |

**SUMMARY OF PROPOSAL FOR PUBLIC RELEASE (Use plain language.)**

**This plain language summary will be available to the public if your proposal is funded. Although it is not mandatory, you may choose to include your business telephone number and/or your e-mail address to facilitate contact with the public and the media about your research.**

Business telephone no. (optional): 1 (905) 5259140 Ext. 20163

E-mail address (optional): junchen@ece.mcmaster.ca

Most existing visual analysis systems are based on the "Compress-Then-Analyze" paradigm, where the analysis is performed on visual features extracted from the already-compressed images or video sequences. In order to exploit the increasing computational capabilities of mobile units, a research team at BlackBerry is developing a smart video processing system according to a new paradigm known as "Analyze-Then-Compress". In this new paradigm, features are first extracted from the raw visual data and then compressed in preparation for further processing, transmission or storage. However, it has been observed that the legacy visual data compression techniques have poor performance when used to compress the visual features extracted from the raw video sequences. Through several technical discussions, we have identified that the source of this problem is the incompatibility of reconstruction-oriented compression and analysis-oriented compression. The proposed project aims to tackle this problem by designing a feature compression algorithm based on the information bottleneck principle. In contrast to the conventional compression algorithms that strive to minimize the reconstruction distortion, the new algorithm is designed to preserve the relevant information contained in the compressed features and consequently has the potential to achieve superior performance in a wide range of visual analysis tasks. This project will provide a cutting-edge video processing technology that will enable BlackBerry to become a major player in developing the new video processing and analysis standard, currently being explored by an ad-hoc MPEG group on Compact Descriptors for Video Analysis. In addition to that, it is expected to build the foundation of a long-term collaboration between BlackBerry and McMaster University in the areas of data mining, privacy protection, and health-related information technologies. On the educational front, the project provides an extraordinary opportunity for students and researchers to acquire valuable experience, skills, and knowledge that are in line with the needs of academia and Canadian information technology industries in the big data era.

**Other Language Version of Summary (optional).**

| Personal identification no. (PIN) | Family name of applicant |
|---|---|
| **Valid** 327936 | Chen |

See instructions for further details.

**PROPOSED EXPENDITURES**

| | Cash | In-kind |
|---|---|---|
| 1) Salaries and benefits | | |
| a) Students | 22,920 | |
| b) Postdoctoral fellows | 0 | |
| c) Technical/professional assistants | 0 | 5,200 |
| d) | 0 | |
| 2) Equipment or facility | | |
| a) Purchase or rental | 0 | 0 |
| b) Operation and maintenance costs | 0 | |
| c) User fees | 0 | 0 |
| d) | 0 | |
| 3) Materials and supplies | | |
| a) | 0 | 0 |
| b) | 0 | |
| c) | 0 | 0 |
| 4) Travel | | |
| a) Conferences | 0 | |
| b) Field work | 0 | 0 |
| c) Project-related travel | 800 | |
| d) Meal | 1,280 | |
| 5) Dissemination | | |
| a) Publication costs | 0 | |
| b) | 0 | |
| 6) Technology transfer activities | | |
| a) Field trials | 0 | |
| b) Prototypes | 0 | |
| c) | 0 | |
| **TOTAL PROPOSED EXPENDITURES** | 25,000 | |
| **Total support from industry** | 0 | |
| **Total support from university** | | |
| **Total support from other sources** | | |
| **AMOUNT REQUESTED FROM NSERC** | 25,000 | |



**PROTECTED WHEN COMPLETED**



Canada

| Personal identification no. (PIN) | Family name of applicant |
|---|---|
| **Valid** 327936 | Chen |

Supporting organizations are not required to make cash or in-kind contributions for this grant. However, if there are any contributions, please report them in the following table, and describe any in-kind contributions provided in the budget justification.

Name of supporting organization

BlackBerry Limited

| **CONTRIBUTIONS FROM SUPPORTING ORGANIZATIONS** | |
|---|---|
| | |
| **Cash contributions to direct costs of research (Transfer amounts to page three (3); except those for the Ship Time program.)** | 0 |
| | |
| **In-kind contributions to direct costs of research** | |
| 1) Salaries for scientific and technical staff | 5,200 |
| 2) Donation of equipment, software | 0 |
| 3) Donation of material | 0 |
| 4) Field work logistics | 0 |
| 5) Provision of services | 0 |
| 6) | 0 |
| **Total of in-kind contributions to direct costs of research** | 5,200 |
| | |
| **In-kind contributions to indirect costs of research (not leveraged)** | |
| 1) Use of organization's facilities | 0 |
| 2) Salaries of managerial and administrative staff | 2,600 |
| 3) | 0 |
| **Total of all in-kind contributions** | 7,800 |
| **Contribution to postsecondary institution overhead** | 0 |



Canada

# Contributions from Supporting Organizations

**In-kind contributions to direct costs of research**

**1) Salaries for scientific and technical staff:** This $5,200 in-kind contribution from BlackBerry is for the salary of Dr. Dake He (26 weeks $\times$ 2 hours/week $\times$ $100/hour = $5,200).

Dr. He is the Director of the Application-and-Security Group within the BlackBerry Standards Team. He is a highly respected researcher in information theory, data compression, and video coding. He will help to establish the research direction and guide the research program to ensure that it stays on path to deliver its intended results. He will also be responsible for knowledge transfer from the research program to the company.

**In-kind contributions to indirect costs of research (not leveraged)**

**2) Salaries of managerial and administrative staf:** This $2,600 in-kind contribution from BlackBerry is for the salary of Gaelle Martin-Cocher (26 weeks $\times$ 1 hour/week $\times$ $100/hour = $2,600).

Gaelle Martin-Cocher is a Manager within the BlackBerry Standards Team. She will provide support to Dr. He in organizing collaboration meetings and other research efforts.

# Budget Justification

**1) Salaries and benefits**

**1.a) Students:** The requested $22,920 in cash from NSERC is for the six-month salaries of two Ph.D. students, Rui Xu and Duo Yang (2 persons $\times$ 6 months/person $\times$ $1,910/month = $22,920). Their monthly salary is determined based on the departmental norms. Rui Xu has a solid background in information theory and extensive experiences in numerical optimization. He will be responsible for collecting the numerical data generated by the local descriptors and for implementing the information-bottleneck optimization procedure. Duo Yang's research interests include multimedia signal processing and probabilistic graphical models. He will use the data collected by Rui Xu to develop the corresponding statistical models. They will work together to construct the feature compressors and incorporate them into the video processing system developed by BlackBerry.

**1.c) Technical/professional assistants:** This $5,200 in-kind contribution from BlackBerry is for the salary of Dr. Dake He (26 weeks $\times$ 2 hours/week $\times$ $100/hour = $5,200).

**4) Travel:** Rui Xu and Duo Yang will visit BlackBerry twice a week during the last two months of the project to facilitate the incorporation of the constructed feature compressors into the BlackBerry video processing system.

**4.c) Project-related travel:** The requested $800 in cash from NSERC is for the car rental when Rui Xu and Duo Yang visit BlackBerry (16 days $\times$ $50/day = $800).

**4.d) Meals:** The requested $1,280 in cash from NSERC is for the meals of Rui Xu and Duo Yang when they visit BlackBerry (2 persons $\times$ 16 days/person $\times$ $40/day = $1,280).

# Relationship to Other Research Support

G. Discovery Grant (NSERC)

**Toward a Fundamental Theory of Gaussian Source-Channel Networks** ($29,000/year for 5 years, 2013 - 2018)

This project (G) aims to develop a theoretical framework for characterizing fundamental performance limits of Gaussian source-channel networks, i.e., network models that consist of vector Gaussian channels with quadratic cost constraint and vector Gaussian sources with quadratic distortion measure. There is no overlap between G and this NSERC Engage Grant application.

Support of highly qualified personnel: Kia Khezeli (Master's student, September 2012 - July 2014), Yifang Chen (Master's student, January 2014 - present), Dania Elzouki (Ph.D. student, September 2014 - present).

# A Rate-Constrained Video Descriptor Based on the Information Bottleneck Principle

### *Overview of the Company-Specific Problem*

As a leading Canadian IT and telecommunication company, BlackBerry Limited plays an outstanding role in the development of many technologies spanning the areas of mobile device management, enterprise mobility management, smart phone and software development. In particular, the Standards Team (ST) of BlackBerry has made significant contributions to multimedia signal processing, compression, and communication technologies. Recently the Application-and-Security Group in the ST has devoted its efforts and resources to a new project—developing a smart video processing system amenable to a wide range of visual analysis tasks (e.g., object instance recognition, object detection and classification, and scene classification). Among other things, the project aims to find a compact representation of visual features extracted from the raw video sequences. Towards this goal, an efficient feature compression method needs to be developed.

Most current visual analysis systems are based on the "Compress-Then-Analyze" paradigm, where the analysis is performed on visual features extracted from the already-compressed images or video sequences. Due to the increasing computational capabilities of mobile units, a new paradigm known as "Analyze-Then-Compress" is gaining popularity in recent years. In this new paradigm, features are first extracted from the raw visual data and then compressed in preparation for further processing, transmission or storage. Although this new paradigm is attractive for many applications, recent findings, reported by the researchers of the ST of BlackBerry as well as others, have brought to light a substantial shortcoming: the legacy visual data compression techniques have poor performance when used to compress the extracted features. Being well known for his expertise in data compression, the PI was contacted by the ST to help investigate this puzzling phenomenon. Following several discussions over the phone, the ST and the PI have identified that the source of the problem is the incompatibility of reconstruction-oriented compression and analysis-oriented compression. In more detail, the classical compression methods aim to ensure a good reconstruction performance in which distortion is minimized subject to a given rate budget. Such methods are not suitable when the main objective is to analyze the data instead of reconstructing the original content. This discrepancy is particularly pronounced in the new paradigm because the distance between features is not well captured by conventional distortion measures. In fact, the choice of distortion measures for the feature space is application-dependent, which is inconsistent with the requirement that the compressed features should be suitable for a wide range of analysis tasks.

### *Research Project*

The information bottleneck (IB) principle is the proposed way to tackle the aforementioned problem. According to this principle, instead of finding the most appropriate distortion measure for the feature space, one should try to preserve the relevant information contained in the compressed features. The resulting lossy compression scheme is universal in the sense that it is not tailored to a specific distortion measure, and is particularly suitable for analysis tasks based on the information divergence. At the heart of the IB principle is an optimization problem that could be used to specify the test channel for the feature compressor. The complexity of the optimization as well as the resulting compressor, however, increases exponentially with the length of the video sequence. To overcome this issue, we propose to reformulate this optimization problem in a sequential form with limited lookahead by exploiting the underlying probabilistic graphical model. This reformulation enables efficient optimization techniques (say, the deterministic annealing algorithm) to be brought to bear upon the problem and, at the same time, retains the capability of exploiting the spatial and temporal correlation between visual features. In addition to providing valuable guidelines for the construction of feature compressors, the IB principle sheds interesting light

on how to utilize the compressed features. Indeed, in contrast to the conventional approaches where the compressed data are decompressed to the original feature space for further analysis, the principle suggests that the visual analysis tasks should be performed in a space determined by the output alphabet of the aforementioned test channel.

The PI plans to carry out the project with the following milestones:

- Months 1&2 — Collect the statistical data of visual features extracted using the local descriptors provided by BlackBerry and use these data to construct the probabilistic graphical models that are needed for the formulation of the optimization problems in the IB framework.
- Months 3&4 — Construct a feature compressor for each local descriptor by solving a corresponding IB optimization problem and make suitable adjustments based on an initial performance test.
- Months 5&6 — Incorporate the constructed feature compressors into the video processing system developed by BlackBerry and conduct a thorough performance comparison based on a large data set and a variety of visual analysis tasks.

### *Research Competence*

The PI is uniquely positioned to undertake this project. He has made significant contributions to the fields of information and coding theory, multimedia signal processing and communications. His contributions are documented in over 90 referred publications. An important theme of his research is the application of optimization techniques in characterizing the fundamental performance limits of lossy source coding and developing practical quantization and data compression schemes. He received several awards for his research, including the Josef Raviv Memorial Postdoctoral Fellowship (2006), the Early Researcher Award from the Province of Ontario (2010), and the IBM Faculty Award (2010). He held the Barber-Gennum Chair in Information Technology from 2008 to 2013, and is currently serving as an Associate Editor for the IEEE Transactions on Information Theory.

### *Contribution to the Technology Transfer*

To facilitate collaboration, the teams at McMaster and BlackBerry will have biweekly joint meetings, in which updates on the conducted research and plans for the coming stages will be discussed. Besides the PI, the McMaster research team will comprise two PhD students, Rui Xu and Duo Yang. On the other side, the BlackBerry team will include Dr. Dake He and Gaelle Martin-Cocher. To ensure a smooth technology transfer, Rui Xu and Duo Yang will visit BlackBerry twice a week during the last two months of the project, and together with the BlackBerry team, they will incorporate the constructed compressors into the video processing system of BlackBerry. The details of the solution and performance evaluations will be documented in technical reports.

### *Benefit to Canada*

This project will benefit both academic and industrial societies in Canada. For BlackBerry, it provides a cutting-edge video processing technology that opens the door for the ST to become a major player in developing the new video processing and analysis standard, currently being explored by an ad-hoc MPEG group on Compact Descriptors for Video Analysis. In addition to that, this Engage Grant is expected to build the foundation of a long-term collaboration between BlackBerry and McMaster University in the areas of data mining, privacy protection, and health-related information technologies. On the educational front, the project provides an extraordinary opportunity for students and researchers to acquire valuable experience, skills, and knowledge that are in line with the needs of academia and Canadian information technology industries in the big data era.