2018 Pacific Northwest Numerical Analysis Seminar

October 13, 2018

University of British Columbia,

Vancouver

Program & Abstracts

Society for Industrial and Applied Mathematics

Pacific Institute for the Mathematical Sciences

Getting Started

Get connected: The "eduroam" network is available at UBC. Another option is the "ubcvisitor" network. Open up a web browser, and you will be directed to the login page.

FAQs

Q: Where are the talks? All talks will be in room 2012.

Q: Where can I go for help on site? If you need assistance or have a question during the meeting, please feel free to talk to Uri Ascher, Chen Greif, or Jessica Bosch.

Q: Where can I get refreshments and meals? For snacks or quick meals, visit http://www.food.ubc.ca/feed-me/ or our web-site https://www.cs.ubc.ca/~greif/PNWNAS2018/map.html. Two coffee breaks are provided.

Q: Where can I get a cab to pick me up from the Venue? You can call Yellow Cab (604-681-1111) and request to be picked up at the back of the building at the intersection of West Mall and Biological Sciences Road.

Q: How can I get around?

- **UBC Map link**: maps.ubc.ca/
- **Public Transit:** Feel free to search and plan your public transport rides by visiting http://www.translink.ca/, where directions, ticket costs and bus schedules are indicated.
- **Parking at UBC:** https://parking.ubc.ca/

Q: Which bus brings me to the dinner place "Banana Leaf"? Bus #14 departs about every 10-15 minutes from UBC's Bus Loop, Bay 11. Exit the bus at Balaclava St. (Broadway at Balaclava St.). Banana Leaf is on the other side of the road.

Q: What emergency numbers should I know?

- **Campus Security (604-822-2222)**
- **General Emergencies (911)**
- **UBC Hospital (604-822-7121)**

There will be photography throughout this event for promotional purposes for use by UBC. If, for any reason, you wish not to have your photo taken or used in this manner, please contact Uri Ascher, Chen Greif, or Jessica Bosch.

Program

08:45 - 09:30 **Registration** (*ESB Atrium*)

09:30 - 09:45 **Welcome: Chen Greif and Uri Ascher** (*ESB 2012*)

09:45 - 10:30 **Plenary: Ron Estrin** (*ESB 2012)*

The Merits of Keeping It Smooth: Implementing a Smooth Exact Penalty Function for Nonlinear Optimization

10:30 - 11:00 **Coffee Break** (*ESB Atrium*)

11:00 - 11:45 **Plenary: Jay Gopalakrishnan** (*ESB 2012)*

Explicit Methods for Hyperbolic Systems on Unstructured Tent Meshes

11:45 - 12:30 **Plenary: Steve Ruuth** (*ESB 2012)*

Linearly Stabilized Schemes for the Time Integration of Stiff Nonlinear PDEs

12:30 - 12:40 **Group Photo** (*ESB Atrium*)

12:40 - 14:00 **Lunch Break** *(on your own)*

14:00 - 14:45 **Plenary: Danny Kaufman** (*ESB 2012)*

Physics in the Rough: Geometric Algorithms for Coarsened Simulation

14:45 - 15:30 **Plenary: Andy Wan** (*ESB 2012)*

Conservative Methods for Dynamical Systems

15:30 - 16:00 **Coffee Break** (*ESB Atrium*)

16:00 - 16:45 **Plenary: Sherry Li** (*ESB 2012)*

Clustering Techniques and Hierarchical Matrix Formats for Kernel Ridge Regression

16:45 - 17:30 **Plenary: Eldad Haber** (*ESB 2012)*

Computational Aspects of Deep Neural Networks

18:30 - 20:30 **Group Dinner** (*Banana Leaf; registration required)*

3005 W. Broadway, Vancouver, BC V6K 2G9

Abstracts

09:45 - 10:30

The Merits of Keeping It Smooth: Implementing a Smooth Exact Penalty Function for Nonlinear Optimization

Ron Estrin, Institute for Computational and Mathematical Engineering, Stanford University

Michael Friedlander, Department of Computer Science, Department of Mathematics, University of British Columbia

Dominique Orban, GERAD, Department of Mathematics and Industrial Engineering, Polytechnique Montréal

Michael Saunders, Systems Optimization Laboratory, Department of Management Science and Engineering, Stanford University

We consider constrained nonlinear programs of the form

$$\underset{x\in R^n}{\text{minimize}} \quad f(x) \quad \text{subject to} \quad c(x)=0, \tag{NP}$$

where f and c are second-order smooth functions. Such models are ubiquitous in the computational sciences, used in applications such as optimal control, seismic imaging, and systems biology. We discuss a penalty function approach originally proposed by [1], where instead of minimizing (NP), we instead minimize the smooth, unconstrained penalty function:

$$\begin{aligned} \underset{x\in R^n}{\text{minimize}} \quad & \phi_\sigma(x) \coloneqq f(x) - y_\sigma(x)^T c(x) \\ & y_\sigma(x) \coloneqq \arg\min_y \frac{1}{2}\|\nabla f(x) - \nabla c(x)^T y\|_2^2 + \sigma c(x)^T y. \end{aligned}$$

This penalty function is *exact* in the sense that minimizers of (NP) are minimizers of ϕ_σ for a sufficiently large (but finite) penalty parameter.

Fletcher originally envisioned that this penalty function would be applied to small, dense problems. We challenge this notion by demonstrating how to compute the quantities necessary for most off-the-shelf optimization solvers with computational cost comparable to widely accepted methods for nonlinear optimization, such as sequential quadratic programming. In particular, we also demonstrate how to combine the penalty function with matrix-free optimization solvers, in order to target large-scale problems, particularly in the case of PDE-constrained optimization.

We discuss further extensions of the penalty function, including regularization for stability, problems with inequality constraints, and the use of inexact evaluations. We also provide some preliminary numerical results on some standard optimization test problems and PDE-constrained problems.

References

[1] R. Fletcher, *A class of methods for nonlinear programming with termination and convergence properties*, In J. Abadie, editor. Integer and nonlinear programming, pp. 157–175. North-Holland, Amsterdam, 1970.

11:00 - 11:45

Explicit Methods for Hyperbolic Systems on Unstructured Tent Meshes

Jay Gopalakrishnan, Portland State University

Tent-shaped spacetime regions appear to be natural for solving hyperbolic systems because one can ensure causality by constraining the height of the tent pole. Specifically, the domain of dependence of all points within a tent can be guaranteed to be contained within the tent by constraining the tent pole height. Moreover, a spacetime simulation region can be covered by advancing fronts of such tents. In this talk, we review known techniques to advance the numerical solution of a hyperbolic problem by progressively meshing a spacetime domain by tent shaped objects. Then we introduce new schemes, called Mapped Tent Pitching (MTP) schemes, which proceed by transforming tents into domains where space and time are separated, allowing standard methods to be used within tents. This technique also allows, for the first time, the use of fully explicit schemes within tents. After highlighting certain difficulties that arise with naive use of standard explicit Runge-Kutta time stepping algorithms in this context, the talk will conclude with themes from ongoing research into new explicit MTP schemes.

References

[1] J. Gopalakrishnan, J. Schöberl, and C. Wintersteiger, *Mapped tent pitching schemes for hyperbolic systems,* SIAM J. Sci. Comput., 39(6), pp. B1043—B1063, 2017.

11:45 - 12:30

Linearly Stabilized Schemes for the Time Integration of Stiff Nonlinear PDEs

Steve Ruuth, Department of Mathematics, Simon Fraser University

In many applications, the governing PDE to be solved numerically contains a stiff component. When this component is linear, the use of an implicit time stepping method that is unencumbered by stability restrictions is preferred. On the other hand, if the stiff component is nonlinear, the complexity and cost per step of using an implicit method is heightened, and the use of explicit methods may be preferred. In this talk, we consider new and existing linearly stabilized schemes for the purpose of integrating stiff nonlinear PDEs in time. These schemes compute the nonlinear term explicitly and, at the cost of solving a linear system with a matrix that is fixed throughout, are unconditionally stable, thus combining the advantages of explicit and implicit methods. Applications are presented to illustrate the use of these methods.

This is joint work with Kevin Chow (Simon Fraser University).

14:00 - 14:45

Physics in the Rough: Geometric Algorithms for Coarsened Simulation

Danny Kaufman, Adobe Research, Seattle

Physical simulation is the job of constructing and implementing discrete structures to mimic behaviors in the world around us. From toy mass-spring systems to high-fidelity representations of reality, physical simulation plays a key role in how we exaggerate, interpret, mediate and predict events. Yet fundamental features of complex dynamic systems, including strong nonlinearities, frictional contact, impact and nonconvexity, pose significant challenges to computation at the high-speed rates required by modern research, entertainment, and industrial applications. To make these applications tractable we necessarily turn to highly coarse representations and often even low-precision solves. And while classical analysis can sometimes provide guarantees for our simulations at high resolutions with accurate solves, all bets are off when we violate these base assumptions. Nevertheless, physical systems must be modeled and, in turn, these models will necessarily be roughly discretized and simulated. It is thus critical to consider how the resulting behaviors of these rough simulations can best be understood, solved and validated. In turn this leads us to ask how can we compute predictive and compelling coarse simulations. Or put simply: what can we squeeze out of simulation "on the cheap"?

In this talk I will present some of our recent investigations towards answering these questions. First, I will discuss our work on designing a coarsening algorithm for the efficient yet predictive simulation of impacting elastica at practical-size time steps and spatial resolutions. Second, I will present a new optimization method for minimizing distortion under extreme deformations at efficient rates. Throughout I will focus on the role geometry plays in these domains and cover a range of applications that our methods enable ranging from the design optimization of 3D-printed jumping mechanisms, to the predictive simulation of emergent patterns in oscillated granular beds, and on to the live-broadcast animation of performed cartoons.

14:45 - 15:30

Conservative Methods for Dynamical Systems

Andy Wan, Department of Mathematics and Statistics, University of Northern British Columbia

Many interesting dynamical systems possess geometric invariants or conserved quantities that are important for understanding their long term behaviours. Conservative methods are numerical methods which preserve these invariants on their numerical solutions. Unfortunately, classical methods, such as linear multistep methods and Runge-Kutta methods, are not conservative for general types of invariants [1]. While projection methods are in general conservative, they can lead to instability over long-term integration if their numerical solutions are projected on to a different connected component. Discrete gradient method [2] is another class of conservative methods, which expresses the differential equations in a skew-gradient tensor form. However, for large dynamical systems with multiple invariants, sparse representations of such tensor form are not known at this time.

In this talk, we introduce a new class of conservative methods, called the multiplier method [3], which can be applied to general dynamical systems with arbitrary forms of invariants, without the need for projection or finding sparse tensor representations. We illustrate this method on a variety of examples, such as non-Hamiltonian systems and large dynamical systems. Also, we will discuss an important connection between conservative methods and long-term stability. Specifically, under appropriate conditions, for conservative methods with a uniformly bounded displacement property, their global error is bounded for all time [4].

This is joint work with Alexander Bihlo (Memorial University of Newfoundland) and Jean-Christophe Nave (McGill University).

References

[1] E. Hairer, C. Lubich, and G. Wanner, *Geometric numerical integration: structure-preserving algorithms for ordinary differential equations,* Springer, Berlin, 2006.

[2] G. R. W. Quispel, R. I. McLachlan and N. Robidoux, *Geometric integration using discrete gradients,* Phil. Trans. R. Soc. Lond., 357, pp. 1021—1045, 1999.

[3] A. T. S. Wan, A. Bihlo and J.-C. Nave, *Conservative methods for dynamical systems,* SIAM J. Numer. Anal., 55(5), pp. 2255—2285, 2017.

[4] A. T. S. Wan and J.-C. Nave, *On the arbitrarily long-term stability of conservative methods,* To appear in SIAM J. Numer. Anal., 25 pages, 2018.

16:00 - 16:45

Clustering Techniques and Hierarchical Matrix Formats for Kernel Ridge Regression

Sherry Li, Lawrence Berkeley National Lab

We present memory-efficient and scalable algorithms for kernel methods used in machine learning. Using hierarchical matrix approximations for the kernel matrix the memory requirements, the number of floating point operations, and the execution time are drastically reduced compared to standard dense linear algebra routines. We consider both the general H-matrix hierarchical format as well as Hierarchically Semi-Separable (HSS) matrices. Furthermore, we investigate the impact of several preprocessing and clustering techniques on the hierarchical matrix compression. Effective clustering of the input leads to a ten-fold increase in efficiency of the compression. The algorithms are implemented using the STRUMPACK solver library. These results confirm that classification using kernel ridge regression with the compressed matrix does not lose prediction accuracy compared to the exact kernel matrix and that our approach can be extended to O(1M) datasets, for which computation with the full kernel matrix becomes prohibitively expensive. We present numerical experiments in a distributed memory environment up to 1,024 processors of the NERSC's Cori supercomputer using well-known datasets to the machine learning community that range from dimension 8 up to 784.

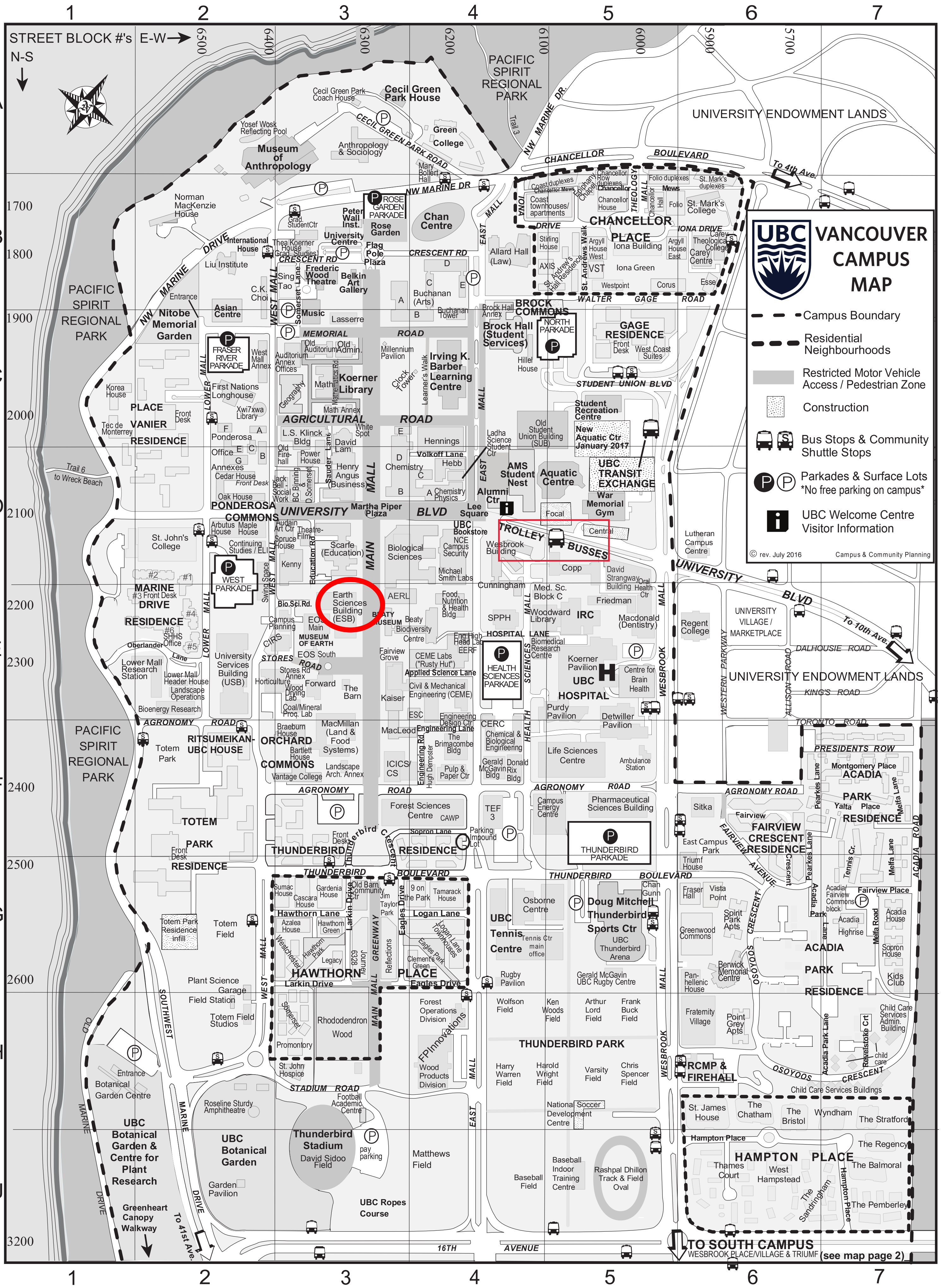
16:45 - 17:30

Computational Aspects of Deep Neural Networks

Eldad Haber, Department of Earth and Ocean Science, University of British Columbia

Partial differential equations (PDEs) are indispensable for modeling many physical phenomena and also commonly used for solving image processing tasks. In the latter area, PDE-based approaches interpret image data as discretizations of multivariate functions and the output of image processing algorithms as solutions to certain PDEs. Posing image processing problems in the infinite dimensional setting provides powerful tools for their analysis and solution. Over the last three decades, the reinterpretation of classical image processing tasks through the PDE lens has been creating multiple celebrated approaches that benefit a vast area of tasks including image segmentation, denoising, registration, and reconstruction. In this work, we establish a new PDE-interpretation of deep convolution neural networks (CNN) that are commonly used for learning tasks involving speech, image, and video data. Our interpretation includes convolution residual neural networks (ResNet), which are among the most promising approaches for tasks such as image classification having improved the state-of-the-art performance in prestigious benchmark challenges. Despite their recent successes, deep ResNets still face some critical challenges associated with their design, immense computational costs and memory requirements, and lack of understanding of their reasoning.

Guided by well-established PDE theory, we derive three new ResNet architectures that fall two new classes: parabolic and hyperbolic CNNs. We demonstrate how PDE theory can provide new insights and algorithms for deep learning and demonstrate the competitiveness of three new CNN architectures using numerical experiments.



UBC VANCOUVER CAMPUS MAP
Campus Boundary
Residential Neighbourhoods
Restricted Motor Vehicle Access / Pedestrian Zone
Construction
Bus Stops & Community Shuttle Stops
Parkades & Surface Lots *No free parking on campus*
UBC Welcome Centre Visitor Information
© rev. July 2016
Campus & Community Planning
STREET BLOCK #'s E-W
N-S
6500
6400
6300
6200
6100
6000
5900
5700
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
3200
PACIFIC SPIRIT REGIONAL PARK
UNIVERSITY ENDOWMENT LANDS
NW MARINE DR.
CHANCELLOR BOULEVARD
To 4th Ave.
Cecil Green Park Coach House
Cecil Green Park House
Yosef Wosk Reflecting Pool
CECIL GREEN PARK ROAD
Green College
Museum of Anthropology
Anthropology & Sociology
Mary Bollert Hall
Norman MacKenzie House
ROSE GARDEN PARKADE
Peter Wall Inst.
Rose Garden
Chan Centre
University Centre
Flag Pole Plaza
CRESCENT RD
International House
Thea Koerner House Grad. Studies
Liu Institute
Frederic Wood Theatre
Belkin Art Gallery
Sing Tao
Buchanan (Arts)
Buchanan Tower
Nitobe Memorial Garden
Asian Centre
C.K. Choi
Music
Lasserre
MEMORIAL ROAD
Allard Hall (Law)
Brock Hall Annex
BROCK COMMONS
Brock Hall (Student Services)
NORTH PARKADE
Hillel House
GAGE RESIDENCE
Front Desk
West Coast Suites
CHANCELLOR PLACE
Iona Building
Iona Green
Coast duplexes
Chancellor Mews
Coast townhouses/ apartments
Epiphany Chapel
Chancellor Row duplexes
Chancellor House
Folio duplexes
Mews
Folio
St. Mark's duplexes
St. Mark's College
Theological College
Carey College
Carey Centre
Argyll House West
Argyll House East
Stirling House
AXIS
St. Andrew's Hall Residence
VST
Westpoint
Corus
Esse
IONA DRIVE
WALTER GAGE ROAD
THEOLOGY MALL
EAST MALL
FRASER RIVER PARKADE
West Mall Annex
Old Auditorium
Old Admin.
Auditorium Annex Offices
Millennium Pavilion
Irving K. Barber Learning Centre
Koerner Library
Math
Math Annex
Clock Tower
Learner's Walk
Geography
First Nations Longhouse
Xwi7xwa Library
Korea House
PLACE VANIER RESIDENCE
Tec de Monterrey
Front Desk
AGRICULTURAL ROAD
STUDENT UNION BLVD
Student Recreation Centre
Old Student Union Building (SUB)
New Aquatic Ctr January 2017
Ladha Science Student Ctr
UBC TRANSIT EXCHANGE
AMS Student Nest
Aquatic Centre
War Memorial Gym
Alumni Ctr
Lee Square
L.S. Klinck Bldg
David Lam
Hennings
Volkoff Lane
Hebb
Chemistry
Power House
Henry Angus (Business)
Old Fire-hall
Jack Bell - Social Work
BC Binning
D. Somerset
Sauder Lane
Ponderosa Office Annexes
Cedar House
Oak House
Front Desk
PONDEROSA COMMONS
UNIVERSITY BLVD
Martha Piper Plaza
A Chemistry Physics
Trail 6 to Wreck Beach
St. John's College
Arbutus House
Maple House
Spruce House
Continuing Studies / ELI
Audain Art Ctr
Theatre-Film
Scarfe (Education)
Kenny
Education Rd
MAIN MALL
Biological Sciences
UBC Bookstore
NCE Campus Security
Michael Smith Labs
Wesbrook Building
TROLLEY BUSSES
Focal
Central
Copp
Cunningham
David Strangway Building
Oral Health Ctr
WEST PARKADE
MARINE DRIVE RESIDENCE
#3 Front Desk
Swing Space
Bio.Sci.Rd.
Earth Sciences Building (ESB)
AERL
Beaty Museum
Beaty Biodiversity Centre
Food, Nutrition & Health Bldg
Med. Sc. Block C
SPPH
Woodward Library
IRC
Friedman
Macdonald (Dentistry)
Campus Planning
EOS Main
MUSEUM OF EARTH
EOS South
CIRS
STORES ROAD
Stores Rd Annex
Engg High Head Lab
EERF
HOSPITAL LANE
Biomedical Research Centre
HEALTH SCIENCES PARKADE
Koerner Pavilion
Centre for Brain Health
UBC HOSPITAL
Purdy Pavilion
Detwiller Pavilion
Oberlander Office
Lower Mall Research Station
Lower Mall Header House
Landscape Operations
University Services Building (USB)
Horticulture
Wood Drying Lab
Forward
The Barn
Kaiser
CEME Labs ("Rusty Hut")
Applied Science Lane
Civil & Mechanical Engineering (CEME)
Fairview Grove
ESC
Engineering Design Ctr
Coal/Mineral Proc. Lab
Bioenergy Research
AGRONOMY ROAD
RITSUMEIKAN-UBC HOUSE
Totem Park
Braeburn House
ORCHARD COMMONS
Bartlett House
Vantage College
MacMillan (Land & Food Systems)
Landscape Arch. Annex
MacLeod
Engineering Lane
The Brimacombe Bldg
ICICS/CS
Pulp & Paper Ctr
Hugh Dempster
CERC
Chemical & Biological Engineering
Gerald McGavin Bldg
Donald Rix Bldg
Life Sciences Centre
Ambulance Station
Regent College
UNIVERSITY VILLAGE / MARKETPLACE
DALHOUSIE ROAD
To 10th Ave.
UNIVERSITY ENDOWMENT LANDS
KING'S ROAD
TORONTO ROAD
WESTERN PARKWAY
ALLISON ROAD
WESBROOK MALL
Lutheran Campus Centre
PRESIDENTS ROW
Montgomery Place
ACADIA PARK RESIDENCE
Yalta Place
Pearkes Lane
Melfa Lane
AGRONOMY ROAD
Sitka
Fairview
FAIRVIEW CRESCENT RESIDENCE
East Campus Park
Triumf House
FAIRVIEW AVENUE
TOTEM PARK RESIDENCE
THUNDERBIRD RESIDENCE
Forest Sciences Centre
CAWP
Sopron Lane
TEF 3
Parking Impound Lot
Campus Energy Centre
Pharmaceutical Sciences Building
THUNDERBIRD PARKADE
THUNDERBIRD BOULEVARD
Sumac House
Gardenia House
Old Barn Community Centre
Cascara House
Jim Taylor Park
9 on the Park
Tamarack House
Hawthorn Lane
Logan Lane
Azalea House
Hawthorn Green
Westchester
Hawthorn Park
Legacy
6328 Journey
Reflections
Clements Green
Eagles Park
Logan Lane Townhouses
HAWTHORN PLACE
Larkin Drive
Eagles Drive
GREENWAY
Osborne Centre
UBC Tennis Centre
Tennis Ctr main office
Doug Mitchell Thunderbird Sports Ctr
UBC Thunderbird Arena
Rugby Pavilion
Gerald McGavin UBC Rugby Centre
Chan Gunn
Fraser Hall
Vista Point
Spirit Park Apts
Greenwood Commons
Berwick Memorial Centre
Pan-hellenic House
Fraternity Village
Point Grey Apts
Acadia Fairview Commons block
Fairview Place
Acadia House
Highrise
Sopron House
Kids Club
Child Care Services Admin. Building
child care
Acadia Park Lane
Revelstoke Crt
OSOYOOS CRESCENT
Child Care Services Buildings
Totem Field
Plant Science Garage
Field Station
Totem Field Studios
Rhododendron Wood
Promontory
St. John Hospice
Forest Operations Division
FPInnovations
Wood Products Division
Wolfson Field
Ken Woods Field
Arthur Lord Field
Frank Buck Field
THUNDERBIRD PARK
Harry Warren Field
Harold Wright Field
Varsity Field
Chris Spencer Field
RCMP & FIREHALL
STADIUM ROAD
Football Academic Centre
Entrance
Botanical Garden Centre
UBC Botanical Garden & Centre for Plant Research
Roseline Sturdy Amphitheatre
UBC Botanical Garden
Thunderbird Stadium
David Sidoo Field
pay parking
Garden Pavilion
Matthews Field
UBC Ropes Course
Greenheart Canopy Walkway
National Soccer Development Centre
Baseball Indoor Training Centre
Baseball Field
Rashpal Dhillon Track & Field Oval
SOUTHWEST MARINE DRIVE
To 41st Ave.
16TH AVENUE
St. James House
The Chatham
The Bristol
Wyndham
The Stratford
Hampton Place
The Regency
HAMPTON PLACE
Thames Court
West Hampstead
The Balmoral
The Sandringham
The Pemberley
TO SOUTH CAMPUS
WESBROOK PLACE/VILLAGE & TRIUMF
(see map page 2)

Map Directory

Site or Building Name & Address	Grid
Abdul Ladha Science Student Ctr, 2055 East Mall	D4
Acadia/Fairview Commonsblock & Front Desk, 2707 Tennis Cres	G7
Acadia House, 2700-2720 Acadia Rd	G7
Acadia Park Residence (Student Family Housing)	F/H-6/7
Acadia Park Highrise, 2725 Melfa Rd	G7
Allard Hall [Faculty of Law], 1822 East Mall	B4
Alumni Centre (Robert H. Lee), 6163 University Blvd	**D4**
AMS Student Nest (new student union building), 6133 University Blvd	**D4**
Anthropology & Sociology (ANSOC) Bldg, 6303 NW Marine Dr	A3
Aquatic Centre (New - opening Jan. 2017), 6080 Student Union Blvd	**C5**
Aquatic Centre (Old), 6121 University Blvd	**D5**
Aquatic Ecosystems Research Lab (AERL), 2202 Main Mall	E3
Asian Centre, 1871 West Mall	B2
Audain Art Centre (in Ponderosa Commons), 6398 University Blvd	D3
Auditorium Annex Offices A & B, 1924 West Mall	C3
Barn ("Owl" child care), 2323 Main Mall	E3
Baseball Indoor Training Centre, 3085 West Mall	J5
B.C. Binning Studios, 6373 University Blvd	D3
Beaty Biodiversity Centre & Museum, 2212 Main Mall	**E3/4**
Belkin (Morris & Helen) Art Gallery, 1825 Main Mall	**B3**
Berwick Memorial Centre, 2765 Osoyoos Cres	G6
Bioenergy Research & Demonstration Facility (BRDF), 2337 Lower Mall	E2
Biological Sciences Bldg, 6270 University Blvd	D3
Biomedical Research Ctr, 2222 Health Sciences Mall	E4
Bollert (Mary) Hall, 6253 NW Marine Dr	A4
Bookstore, 6200 University Blvd	D4
Botanical Garden Centre/Gatehouse, 6804 SW Marine Dr	**H1**
Botanical Garden Pavilion (enter at Gatehouse, 6804 SW Marine Dr)	J2
Botan. Gard. Greenhses/ Workshops, 3929 Wesbrook Mall	South Campus
Brimacombe Building, 2355 East Mall	F4
Brock Commons - Tallwood House (construction), 6088 Walter Gage Rd	B4
BROCK HALL: Student Services & Welcome Centre, 1874 East Mall	**C4**
Brock Hall Annex, 1874 East Mall	C4
Buchanan Building (Blocks A, B, C, D, & E) [Arts], 1866 Main Mall	B3/4
Buchanan Tower, 1873 East Mall	C4
Building Ops Nursery/Greenhouses, 6029 Nurseries Rd	South Campus
C.K. Choi Building for the Institute of Asian Research, 1855 West Mall	B2
Campus & Community Planning, 2210 West Mall	E3
Campus Energy Centre, 6130 Agronomy Rd	F5
Campus Security, 2133 East Mall	D4
Carey Centre / Theological College, 5920 Iona Drive/1815 Wesbrook Mall	B6
Cecil Green Park Coach House, 6323 Cecil Green Park Rd	A3
Cecil Green Park House, 6251 Cecil Green Park Rd	A3
Centre for Brain Health (Djavad Mowafaghian), 2215 Wesbrook Mall	E5
Centre for Comparative Medicine (CCM), 4145 Wesbrook Mall	South Campus
Chan Centre for the Performing Arts, 6265 Crescent Rd	**B4**
Chan Gunn Pavilion (new sports med. construction), 2553 Wesbrook Mall	G5
Chemical & Biological Engineering Bldg, 2360 East Mall	F4
Chemistry A Block - Chemistry Physics Building, 6221 University Blvd	D4
Chemistry B,C,D & E Blocks, 2036 Main Mall	D3
Child Care Services Administration Bldg, 2881 Acadia Rd	H7
Child Care Services Bldgs, Osoyoos Crescent and Revelstoke Crt	H7
CIRS (Centre for Interactive Research on Sustainability), 2260 West Mall	E3
Civil & Mechanical Engineering Bldg (CEME), 6250 Applied Science Lane	E4
Civil & Mechanical Eng. Labs ("Rusty Hut"), 2275 East Mall	E4
Coal & Mineral Processing Lab, 2332 West Mall	E3
Continuing Studies Bldg [English Language Institute], 2121 West Mall	D2
Copp (D.H.) Building, 2146 Health Sciences Mall	D5
Cunningham (George) Building, 2146 East Mall	E4
David Lam Learning Centre, 6326 Agricultural Rd	C3
David Lam Management Research Ctr, 2033 Main Mall	C3
David Strangway Building, 5950 University Blvd	D5
Donald Rix Building, 2389 Health Sciences Mall	F4
Doug Mitchell Thunderbird Sports Centre, 6066 Thunderbird Blvd	**G5**
Dorothy Somerset Studios, 6361 University Blvd	**D3**
Earth Sciences Building (ESB), 2207 Main Mall	E3
Earth & Ocean Sciences (EOS) - Main and South, 6339 Stores Rd	E3
Earthquake Engineering Research Facility (EERF), 2235 East Mall	E4
Engineering High Head Room Lab, 2225 East Mall	E4
Engineering Student Centre, 2335 Engineering Road	E4
English Language Institute (E.L.I.) — *see Continuing Studies Building*	
Environmental Services Facility, 6025 Nurseries Rd	South Campus
Fairview Crescent Residence, 2600-2804 Fairview Cres	F6
Fire Hall, 2992 Wesbrook Mall	H6
First Nations Longhouse, 1985 West Mall	C2
Flag Pole Plaza (Main Mall & Crescent Rd)	B3
Food, Nutrition and Health Bldg, 2205 East Mall	E4
Forest Sciences Centre [Faculty of Forestry], 2424 Main Mall	F4
Forward (Frank) Building, 6350 Stores Rd	E3
FPInnovations, 2601 & 2665 East Mall	H4
Fraser Hall, 2550 Wesbrook Mall	G6
Fraternity Village, 2880 Wesbrook Mall	H6
Frederic Wood Theatre, 6354 Crescent Rd	**B3**
Friedman Bldg, 2177 Wesbrook Mall	E5
Gage (Walter H.) Residence, 5959 Student Union Blvd	C5
Geography Building, 1984 West Mall	C3
Gerald McGavin Building, 2386 East Mall	F4
Gerald McGavin UBC Rugby Centre, 2765 Wesbrook Mall	G5
Graduate Student Centre — *see Thea Koerner House*	
Green College, 6201 Cecil Green Park Rd	A4
Hebb Building, 2045 East Mall	D4
Hennings Building, 6224 Agricultural Rd	C4
Henry Angus Building [Sauder School of Business], 2053 Main Mall	D3
Hillel House, 6145 Student Union Blvd	C4
Horticulture Building/Greenhouse, 6394 Stores Rd	E2/3

Site or Building Name & Address	Grid
Hugh Dempster Pavilion, 6245 Agronomy Rd	F4
ICICS/CS (Institute for Computing, Information & Cognitive Systems/Computer Science), 2366 Main Mall	F4
Instructional Resources Centre (IRC), 2194 Health Sciences Mall	E5
International House, 1783 West Mall	B2
In-Vessel Composting Facility, 6035 Nurseries Road	South Campus
Irving K. Barber Learning Centre, 1961 East Mall	**C4**
Jack Bell Building for the School of Social Work, 2080 West Mall	D3
Kaiser (Fred) Building [Faculty of Applied Science], 2332 Main Mall	E3
Kenny (Douglas T) Building, [Psychology] 2136 West Mall	D3
Kids Club, 2855 Acadia Rd	G7
Klinck (Leonard S.) Bldg, 6356 Agricultural Rd	C3
Koerner (Walter C.) Library, 1958 Main Mall	C3
Landscape Architecture Annex, 2371 Main Mall	F3
Lasserre (Frederic) Building, 6333 Memorial Rd	C3
Library Preservation Archives (PARC), 6049 Nurseries Rd	South Campus
Life Sciences Centre, 2350 Health Sciences Mall	F5
Liu Institute for Global Issues, 6476 NW Marine Dr	B2
Lower Mall Research Station, 2259 Lower Mall	E2
Macdonald (J.B.) Building [Dentistry], 2199 Wesbrook Mall	E5
MacLeod (Hector) Building, 2356 Main Mall	F3
MacMillan (H.R.) Bldg [Faculty of Land & Food Systems], 2357 Main Mall	F3
Marine Drive Residence (Front Desk in Bldg #3), 2205 Lower Mall	E2
Material Recovery Facility, 6055 Nurseries Rd	South Campus
Mathematics Annex, 1986 Mathematics Rd	C3
Mathematics Building, 1984 Mathematics Rd	C3
Medical Sciences Block C, 2176 Health Sc. Mall	E4
Michael Smith Laboratories, 2185 East Mall	D4
Museum of Anthropology (MOA), 6393 NW Marine Dr	**A2/3**
Music Building, 6361 Memorial Rd	B/C3
National Soccer Development Centre, 3065 Wesbrook Mall	H5
Networks of Ctrs of Excellence (NCE), 2125 East Mall	D4
Nitobe Memorial Garden, 1895 Lower Mall	B/C2
Nobel Biocare Oral Heath Centre, 2151 Wesbrook Mall	E5
Norman MacKenzie House, 6565 NW Marine Dr	B2
NRC Institute for Fuel Cell Innovation, 4250 Wesbrook Mall	South Campus
Old Administration Building, 6328 Memorial Rd	C3
Old Auditorium, 6344 Memorial Rd	C3
Old Barn Community Centre, 6308 Thunderbird Blvd	G3
Old Firehall, 2038 West Mall	D3
Orchard Commons, 6363 Agronomy Rd	F3
Osborne (Robert F.) Centre/Gym, 6108 Thunderbird Blvd	G4
Pacific Museum of Earth (in EOS-Main), 6339 Stores Rd	**E3**
Panhellenic House, 2770 Wesbrook Mall	G6
Peter Wall Institute for Advanced Studies (PWIAS), 6331 Crescent Rd	B3
Pharmaceutical Sciences Building, 2405 Wesbrook Mall	F5
Place Vanier Residence, 1935 Lower Mall	C/D2
Plant Science Field Station & Garage, 2613 West Mall	H2
Point Grey Apartments, 2875 Osoyoos Cresc	H6
Police (RCMP) & Fire Department, 2990/2992 Wesbrook Mall	H6
PONDEROSA COMMONS, University Blvd & West Mall	D2/3
Arbutus & Maple Houses, 6488 University Blvd.	D2
Cedar House (Ponderosa Commons Front Desk), 2075 West Mall	D2
Oak House, 6445 University Blvd	D2
Spruce House, 2118 West Mall	D3

Site or Building Name & Address	Grid
Ponderosa Office Annexes: A, B, & C, 2011-2029 West Mall	C/D2
Ponderosa Office Annexes: E, F & G, 2008-2044 Lower Mall	C/D2
Power House, 2040 West Mall	D3
Pulp and Paper Centre, 2385 East Mall	F4
Ritsumeikan-UBC House, 6460 Agronomy Rd	F2
Rose Garden	B3
Rugby Pavilion, 2584 East Mall	G4
Scarfe (Neville) Building [Education], 2125 Main Mall	D3
School of Population & Public Health (SPPH), 2206 East Mall	E4
SERC (Staging Environmental Research Ctr), 6045 Nurseries Rd	S.Campus
Sing Tao Building, 6388 Crescent Rd	B3
Sopron House, 2730 Acadia Rd	G7
South Campus Warehouse, 6116 Nurseries Rd	South Campus
Spirit Park Apartments, 2705-2725 Osoyoos Cresc	G8
St. Andrew's Hall/Residence, 6040 Iona Dr	B5
St. John Hospice, 6389 Stadium Road	H3
St. John's College, 2111 Lower Mall	D2
St. Mark's College, 5935 Iona Dr.	B6
Stores Road Annex, 6368 Stores Rd	E3
Student Family Housing (Acadia Park Residence)	F/H-6/7
Student Recreation Centre, 6000 Student Union Blvd	C5
Student Union Bldg (old) (Old SUB), 6138 Student Union Blvd	**C4**
TEF3 (Technology Enterprise Facility 3), 6190 Agronomy Rd	F4
Thea Koerner House [Faculty of Graduate Studies], 6371 Crescent Rd	B3
Theatre-Film Production Bldg, 6358 University Blvd	D3
Thunderbird Residence, 6335 Thunderbird Cresc	F3/4
Thunderbird Arena (in Doug Mitchell Centre), 2555 Wesbrook Mall	G5
Thunderbird Stadium, 6288 Stadium Rd	J3
Totem Field Studios, 2613 West Mall	H2
Totem Park Residence, 2525 West Mall	F/G2
TRIUMF, 4004 Wesbrook Mall	South Campus
Triumf House (TRIUMF Visitors' Residence), 5835 Thunderbird Blvd	G6
UBC Bookstore, 6200 University Blvd	**D4**
UBC Farm, 3461 Ross Drive	**South Campus**
UBC Football Academic Centre, 6298 Stadium Rd	H3
UBC Hospital, 2211 Wesbrook Mall	E5
UBC Parking Impound Lot, 2451 East Mall	F4
UBC Tennis Centre, 6160 Thunderbird Blvd	G4
University Centre (Leon & Thea Koerner), 6331 Crescent Rd	B3
University Services Building (USB), 2329 West Mall	E2
Vancouver School of Theology (VST), 6015 Walter Gage Rd	B5
Vantage College (in Orchard Commons, Fall 2016), 6363 Agronomy Rd	F3
War Memorial Gymnasium, 6081 University Blvd	D5
Wayne & William White Engineering Design Ctr, 2345 East Mall	E4
Wesbrook Bldg, 6174 University Blvd	D4
Wesbrook Community Centre, 5998 Berton Ave	South Campus
Wesbrook Village commercial centre	South Campus
West Mall Annex, 1933 West Mall	C2
West Mall Swing Space Bldg, 2175 West Mall	D2
Wood Drying Laboratory, 2324 West Mall	E3
Woodward IRC, 2194 Health Sciences Mall	E4/5
Woodward Library, 2198 Health Sciences Mall	E4/5