Centre International de Mathématiques Pures et Appliquées (CIMPA)

Hanoi Institute of Mathematics Vietnam Academy of Science and Technology (VAST)

CIMPA-UNESCO-VIETNAM SCHOOL

Variational Inequalities and Related Problems

Hanoi, May 10-21, 2010

PROGRAM and ABSTRACTS

Institute of Mathematics, Hanoi, 2010

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PROGRAM

Monday, May 10, 2010

08:15 –09:00 Registration

09:00– 09:30 Opening Ceremony

09:30 – 10:45 Dinh The Luc

Variational relations in infinite dimension (Lecture 1)

10:45 – 11:00 Coffee Break

11:00 – 12:15 Didier Aussel

Existence and unicity results for variational inequalities (Lecture 1)

12:15 – 14:00 Lunch Break

14:00 – 15:45 Jong-Shi Pang

Numerical analysis of variational inequalities (Lecture 1)

15:45– 16:00 Coffee Break

16:00– 17:00 Scientific Seminar

Chair: **Phan Quoc Khanh**

16:00 – 16:30 **Truong Quang Bao**

Subdifferential necessary conditions for generalized-order optimal solutions in constrained set-valued optimization

16:30 – 17:00 **Dhara Anueleka**

A brief tour of optimality conditions in convex programming

Tuesday, May 11, 2010

08:15 – 10:00 Dinh The Luc

Variational relations in infinite dimension (Lecture 2)

10:00 – 10:15 Coffee Break

10:15 – 12:00 Boris Mordukhovich

Introduction to Variational Analysis (Lecture 1)

12:00– 14:00 Lunch Break

14:00– 15:45 Nguyen Dong Yen

Stability/sensitivity of parametric variational inequalities (Lecture 1)

15:45– 16:00 Coffee Break

16:00– 17:00 Scientific Seminar

Chair: **Shashi Kant Mishra**

16:00 – 16:30 **Nguyen Thi Thu Thuy**

Mixed variational inequalities: regularized solutions and convergence rates

16:30 – 17:00 **Kosuru Gowri Sankara Raju**

On existence and convergence of best proximity pair theorems

Wednesday, May 12, 2010

08:15 – 10:00 Didier Aussel

Existence and unicity results for variational inequalities (Lecture 2)

10:00 – 10:15 Coffee Break

10:15 – 12:00 Boris Mordukhovich

Introduction to Variational Analysis (Lecture 2)

12:00– 14:00 Lunch Break

14:00– 15:45 Jong-Shi Pang

Numerical analysis of variational inequalities (Lecture 2)

15:45– 16:00 Coffee Break

16:00– 17:00 Scientific Seminar

Chair: **Bui Trong Kien**

16:00 – 16:30 **Boris Mordukhovhich and Tran Thai An Nghia**

Constraint qualification and optimality conditions in semi-infinite and infinite programming

16:30 – 17:00 **Thai Doan Chuong and Jen-Chih Yao**

Sufficient conditions for pseudo-Lipschitz property in convex semi-infinite vector optimization problems

Thursday, May 13, 2010

08:15 – 10:00 Dinh The Luc

Variational relations in infinite dimension (Lecture 3)

10:00 – 10:15 Coffee Break

10:15 – 12:00 Boris Mordukhovich

Introduction to Variational Analysis (Lecture 3)

12:00– 14:00 Lunch Break

14:00– 15:45 Didier Aussel

Existence and unicity results for variational inequalities (Lecture 3)

15:45– 16:00 Coffee Break

16:00– 17:00 Scientific Seminar

Chair: **Le Dung Muu**

16:00 – 16:30 **Phan Quoc Khanh, Vo Si Trong Long and Nguyen Hong Quan**

Continuous selections, collectively fixed points and weakly T-KKM theorems in GFC-spaces

16:30 – 17:00 **Javid Ali**

Common fixed points of non-self mappings in metrically convex spaces

Friday, May 14, 2010

08:15 – 10:00 Masao Fukushima

Applications in operations research (Lecture 1)

10:00 – 10:15 Coffee Break

10:15 – 12:00 Boris Mordukhovich

Introduction to Variational Analysis (Lecture 4)

12:00– 14:00 Lunch Break

14:00– 15:45 Jong-Shi Pang

Numerical analysis of variational inequalities (Lecture 3)

15:45– 16:00 Coffee Break

16:00– 17:00 Scientific Seminar

Chair: **Nguyen Xuan Tan**

16:00 – 16:30 **Phan Thanh An**

Stability of generalized monotone maps

16:30 – 17:00 **Melanie Joyno Orig**

College mathematical readiness of the senior high school students in district I of Davao city

Saturday, May 15, 2010

13:00-18:30 City Tour

Sunday, May 16, 2010

06:30-20:00 Excursion: Ha Long Bay

Monday, May 17, 2010

08:15 –10:00 Masao Fukushima

Applications in operations research (Lecture 2)

10:00 – 10:15 Coffee Break

10:15 – 12:00 Marc Lassonde

Introduction to variational inequalities and basic tools (Lecture 1)

12:00 – 14:00 Lunch Break

14:00 – 15:45 Jong-Shi Pang

Numerical analysis of variational inequalities (Lecture 4)

15:45– 16:00 Coffee Break

16:00– 17:00 Scientific Seminar

Chair: **Phan Thanh An**

16:00 – 16:30 **Boris Mordukhovich and Phan Minh Hung**

Tangential extremal principle and applications

16:30 – 17:00 **Arcede Jayrold P.**

An equivalent defnition for the backwards Itô integral

Tuesday, May 18, 2010

08:15 – 10:00 Masao Fukushima

Applications in operations research (Lecture 3)

10:00 – 10:15 Coffee Break

10:15 – 12:00 Didier Aussel

Existence and unicity results for variational inequalities (Lecture 4**)**

12:00– 14:00 Lunch Break

14:00– 15:45 Nguyen Dong Yen

Stability/sensitivity of parametric variational inequalities (Lecture 2)

15:45– 16:00 Coffee Break

16:00– 17:00 Scientific Seminar

Chair: **Nguyen Nang Tam**

16:00 – 16:30 **Nguyen Huy Chieu**

Relationships between Robinson metric regularity and Lipschitz-like behavior of implicit multifunctions

16:30 – 17:00 **Nguyen Song Ha and Ta Duy Phuong**

Some remarks on the structure of solution sets of affine vector variational inequalities

Wednesday, May 19, 2010

08:15 – 10:00 Masao Fukushima

Applications in operations research (Lecture 4)

10:00 – 10:15 Coffee Break

10:15 – 12:00 Marc Lassonde

Introduction to variational inequalities and basic tools (Lecture 2)

12:00– 14:00 Lunch Break

14:00– 15:45 Nguyen Dong Yen

Stability/sensitivity of parametric variational inequalities (Lecture 3)

15:45– 16:00 Coffee Break

16:00– 17:00 Scientific Seminar

Chair: **Ta Quang Son**

16:00 – 16:30 **Lam Quoc Anh and Nguyen Van Hung**

Semicontinuity of the solutions set of parametric vector quasiequilibrium problem

16:30 – 17:00 **Le Minh Luu and Tran Trinh Minh Son**

Stability of Pareto-Nash equilibriums of multi-objective games

Thursday, May 20, 2010

08:15 – 10:00 Dinh The Luc

Variational relations in infinite dimension (Lecture 4)

10:00 – 10:15 Coffee Break

10:15 – 12:00 Marc Lassonde

Introduction to variational inequalities and basic tools (Lecture 3)

12:00– 14:00 Lunch Break

14:00– 15:45 Nguyen Dong Yen

Stability/sensitivity of parametric variational inequalities (Lecture 4)

15:45– 16:15 Closing Ceremony

16:15– 17:30 Farewell Dinner

List of Lectures

List of Talks at Scientific Seminars

ABSTRACTS OF LECTURES

Existence, unicity and applications for set-valued variational inequalities

Didier Aussel[1]

Our aim in this course is to present existence results for variational inequalities of different types. We will first introduce the main classes of variational inequalities and describe the relations between them. Then we will turn our attention on existence results for those variational inequalities. It is interesting to go back to some historical considerations to have a good overview of the different technics which have been used to prove existence of solutions. This historical introduction will be naturally followed by the recent extensions for Minty, Stampacchia and quasivariational problems. Uniqueness will also be considered.

One of the main motivation to study variational inequalities comes from the fact that they furnish a perfect setting to express optimality conditions for constrainted optimization problems. We will thus illustrate how the most recent existence results for VI can influence the development of new approaches for modern optimization throught the examples of quasiconvex optimization, MPEC and complex problems arising in economy.

Keywords: Set-valued variational inequalities, existence, unicity

References:

• K. J. Arrow, G. Debreu, Existence of an equilibrium for a competitive economy, *Econometrica* 22 (1954), 265–290.

• Crouzeix, J.-P., Pseudomonotone Variational Inequality Problems: Existence of Solutions, *Mathematical Programming*, Vol. 78 (1997), pp. 305–314.

• Daniilidis, A., and Hadjisavvas, N., Existence Theorems for Vector Variational Inequalities, *Bulletin of the Australian Mathematical Society*, Vol. 54, 473–481, 1996.

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[1]Lab. Promes, University of Perpignan, Rambla de la thermodynamique, 66100 Perpignan. Email: *aussel@univ-perp.fr*

- Daniilidis, A., and Hadjisavvas, N., N., Characterization of Nonsmooth Semistrictly Quasiconvex and Strictly Quasiconvex Functions, *Journal of Optimization Theory and Applications*, Vol. 102 (1999), 525-536.

- Facchinei F., Pang J. S., 2003, *Finite-dimensional variational inequalities and complementarity problems*. Springer, New York.

- P. Hartman and G. Stampacchia, On some nonlinear elliptic functional differential equations, *Acta Math.* 115 (1966), 271–310.

- Mordukhovich, B.S., 2006, *Variational Analysis and Generalized Differentiation*, Vol. 1: Basic Theory, Vol. 2: Applications. Springer, Berlin.

Applications in Operations Research

Masao Fukushima[1]

This course consists of four lectures.

Traffic Equilibrium and Variational Inequalities: The traffic equilibrium problem is one of the earliest applications of variational inequalities in the area of operations research. First we recall Wardrop's principle that plays a fundamental role in the traffic equilibrium theory. We discuss the case of symmetric costs that yields an optimization model of traffic equilibria, and then the case of more general asymmetric costs that yields a variational inequality model. Finally we mention some extensions including the elastic travel demand model and the non-additive route cost model.

Equilibrium Problems under Uncertainty: In real-world applications, the problem data often contain uncertainty. Unlike stochastic optimization problems, the stochastic version of equilibrium problems has not been studied extensively until recently. We first use two examples from traffic equilibria and option pricing to illustrate the stochastic linear complementarity problems. We then discuss two deterministic formulations of stochastic complementarity problems; expected value (EV) model and expected residual minimization (ERM) model. Finally we mention the ERM formulation of stochastic variational inequality problems.

MPEC and SMPEC: The mathematical program with equilibrium constraints (MPEC) has been studied extensively in the past two decades. We use two examples from Stackelberg (leader-follower) game and road traffic management to illustrate MPEC models. We then briefly recall some theoretical aspects of MPECs. Finally we discuss a stochastic version of MPEC, called the stochastic mathematical program with equilibrium constraints (SMPEC), and show that SMPEC may be formulated as two different models, the lower-level wait-and-see model and the here-and-now

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model, depending on when the lower-level and the upper-level decisions are made.

Game Theory and Variational Inequalities: In game theory, variational inequalities and complementarity problems play an important role. For an N-person non-cooperative game, we formally define the solution concept of a Nash equilibrium. We give a variational inequality formulation of an N-person game, thereby arguing existence and uniqueness of an equilibrium. We then consider a generalized Nash equilibrium in a game where the strategy set of each player depends on the other players' strategies. We discuss the relation between generalized Nash equilibria and quasi-variational inequalities, as well as the relation between a particular class of generalized Nash equilibria called normalized equilibria and variational inequalities.

Keywords:

Traffic equilibrium, stochastic equilibrium problem, MPEC, stochastic MPEC, Nash equilibrium, generalized Nash equilibrium.

References:

- R.P. Agdeppa, N. Yamashita and M. Fukushima, The traffic equilibrium problem with nonadditive costs and its monotone mixed complementarity problem formulation, *Transportation research* B41 (2007), 862--874.

- X. Chen and M. Fukushima, Expected residual minimization method for stochastic linear complementarity problems, *Mathematics of Operations Research* 30 (2005), 1022--1038.

- S. Dafermos, Traffic equilibrium and variational inequalities, *Transportation Science* 14 (1980), 42--54.

- F. Facchinei and C. Kanzow, Generalized Nash equilibrium problems, *4OR - A Quarterly Journal of Operations Research* 5 (2007), 173--210.

- F. Facchinei and J.-S. Pang, *Finite-Dimensional Variational Inequalities and Complementarity Problems*, Volume 1, Chapter 1, Section 1.4, Springer 2003.

- M. Fukushima, Restricted generalized Nash equilibria and controlled penalty algorithm, *Computational Management Science* (forthcoming).
- P. T. Harker, Generalized Nash games and quasi-variational inequalities, *European Journal of Operational Research* 54 (1991), 81--94.
- G. H. Lin, X. Chen and M. Fukushima, Solving stochastic mathematical programs with equilibrium constraints via approximation and smoothing implicit programming with penalization, *Mathematical Programming* 116 (2009), 343--368.
- G. H. Lin and M. Fukushima, Stochastic equilium problems and stochastic mathematical programs with equilibrium constraints, *Pacific Journal of Optimization* (forthcoming).
- Z. Q. Luo, J.-S. Pang and D. Ralph, *Mathematical Programs with Equilibrium Constraints*, Cambridge University Press, 1996.
- J.B. Rosen, Existence and uniqueness of equilibrium points for concave N -person games, *Econometrica* 33 (1965), 520--534.

Introduction to variational inequalities and basic tools

Marc Lassonde[1]

This mini-course is divided into two parts, as follows.

Basic tools: Intersection theorems of Sperner, KKM, and Klee; Fixed point theorems of Brouwer, Fan-Browder, and Kakutani-Fan-Glicsberg; Minimax inequality of Ky Fan, Minimax equality of Sion.

Variational inequalities: Applications of the basic tools to the variational inequalities theory.

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Variational Relations in Infinite Dimension

Dinh The Luc[1]

Lecture 1. We analyse several models of variational inequalities, complementarity, equilibrium and optimisation, and show their common features which lead to an abstract problem of variational analysis. Existence conditions are discussed in the context of convex problems through the classical tools such as fixed point theorems and intersection theorems.

Lecture 2. We focus on variational relation problems without convexity. The concept of intersectional closedness is used which broadens a range of applications of the finite intersection principle and leads to new existence criteria. Concrete models from economics and analysis are treated without convexity hypothesis.

Lecture 3. We devote this lecture to the stability of the solution set of a parametric variational relation problem. Outer and inner continuities are our main concerns that are to be established by new kinds of limits for set-valued maps.

Lecture 4. The last lecture presents an extension to a system of variational relations and discussions on how to further study variational relation problems and exploit their tools for applications in other areas.

References:

1. D. T. Luc, An abstract problem of variational analysis, JOTA 138(2008), 65-76.
2. P. Q. Khanh and D. T. Luc, Stability of solutions in parametric variational relation problems, SVA 16(2008), 1015-1035.
3. D. T. Luc, E. Sarabi and A. Soubeyran, Existence of solutions in variational relation problems without convexity, JMAA 364(2010), 544-555.

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Introduction to Variational Analysis

Boris Mordukhovich[1]

This course consists of 4 lectures (2 hours each) devoted to basic principles and constructions of advanced variational analysis and related tools of generalized differentiation.

Recent years have witnessed a rapid development of modern variational analysis, which has become a fruitful area of mathematics with a strong emphasis on applications. From one point of view, variational analysis can be considered as an outgrowth of the classical calculus of variations, optimal control theory, and mathematical programming. On the other hand, this discipline based on variational principles and generalized differentiation has been constituted and well recognized for its own sake. It largely unifies the aforementioned and related areas of applied mathematics and employs variational ideas and techniques to the study of a broad spectrum of mathematical and applied problems, which may not be of a variational/optimization nature.

A strong interest to variational analysis and its applications has dramatically increased after publishing the now classical book ``Variational Analysis" by Rockafellar and Wets [RW98] that provides a systematic exposition and thorough development of key issues of variational analysis in finite-dimensional spaces. Since that time a lot of work has been done in both finite-dimensional and infinite-dimensional variational theory and in great many applications to different branches of mathematics and applied sciences.

More recent developments and applications of variational analysis have been summarized in several books (see, e.g., [ABM05, BZ05, JL08, Mor06a, Mor06b, Sc07]) and in special issues of the leading journals on applied mathematics along with numerous single papers. Quite recently Springer has launched a new high-ranking journal *Set-Valued and*

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Variational Analysis (replacing the former“Set-Valued Analysis”.

It has been well recognized that nonsmooth structures appear naturally and frequently in common analysis and optimization frameworks not only for problems with nonsmooth initial data but also while using basic variational techniques that particularly employ perturbation, approximation, and penalization procedures. This brings tools and results of *generalized differentiation* into the heart of variational analysis and its applications.

In the lectures we overview some key achievements and trends in variational, analysis, generalized differentiations, and their applications particularly to optimization-related problems. Along with well-recognized results, we intend to present some recent as well as brand new developments and applications of variational analysis.

The *plan* of the lectures is as follows:

Lecture 1: *Basic Constructions and Calculus Rules of Generalized Differentiation*.

Lecture 2: *Extremal Principle in Variational Analysis*.

Lecture 3: *Applications to Stability of Constrained and Variational Systems*.

Lecture 4: *Applications to Optimization and Equilibria*.

We are mainly based on the books of the lecturer [Mor06a, Mor06b] as well as on more recent publications.

References:

[ABM05] H. Attouch, G. Buttazzo and G. Michaille, *Variational Analysis in Sobolev and BV Spaces: Applications to PDEs and Optimization*, SIAM, Philadelphia, 2005.

[BZ05] J. M. Borwein and Q. J. Zhu, *Techniques of Variational Analysis*, Springer, New York, 2005.

[FP03] F. Facchinei and J.-S. Pang, *Finite-Dimensional Variational Inequalities and Complementarity Problems*, Springer, New York, 2003.

[JL08] V. Jeyakumar and D. T. Luc, *Nonsmooth Vector Functions and Continuous Optimization*, Springer, New York, 2008.

[Mor06a] B. S. Mordukhovich, *Variational Analysis and Generalized Differentiation, I: Basic Theory*, Springer, Berlin, 2006.

[Mor06b] B. S. Mordukhovich, *Variational Analysis and Generalized Differentiation, II: Applications*, Springer, Berlin, 2006.

[RW98] R. T. Rockafellar and R. J-B. Wets, *Variational Analysis*, Springer, Berlin, 1998.

[Sc07] W. Schirotzek, *Nonsmooth Analysis*, Springer, Berlin, 2007.

Numerical Methods for Complementarity Problems, Variational Inequalities, and Extended Systems

Jong-Shi Pang[1]

These 4 lectures focus on numerical methods for solving complementarity problems (CPs) and variational inequalities (VIs). The plan for these lectures is as follows.

Lecture I: We will present Lemke's method for solving linear complementarity problems (LCPs) and its extension to affine variational inequalities (AVIs). A new condition for this algorithm to successfully compute a solution to a LCP with a semi-copositive matrix is highlighted and illustrated with applications.

Lecture II: We will describe the Josephy-Newton linearization method for solving variational inequalities and present its convergence theory via the property of solution stability. An alternative approach for solving complementarity problems based on the theory of C(omplementarity)-functions is also presented.

Lecture III: We will describe special methods for solving monotone problems that include the projection methods and Tikhonov regularization and present their convergence theory. Partitioned VIs defined Cartesian products of lower-dimensional sets are amenable to decomposition methods of the Gauss-Seidel and Jacobi type that are the basis for the design of distributed algorithms.

Lecture IV: We will introduce the class of differential variational inequalities (DVIs) and present time-stepping methods for their numerical solution. The DVI is a new mathematical paradigm that models dynamical

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systems undergoing mode changes over time and subject to variational conditions such as inequality constraints. An application of the methodology to linear-quadratic optimal control problems with state and control constraints is described.

Keywords: complementarity problems, Newton-type methods, nonsmooth equations, monotone problems, differential variational systems.

References:

• R. W. Cottle, J. S. Pang and R. E. Stone. *The Linear Complementarity Problem*, SIAM Classics in Applied Mathematics 60, Philadelphia (2009) [Originally published by Academic Press, Boston (1992)].

• F. Facchinei and J. S. Pang. *Finite-Dimensional Variational Inequalities and Complementarity Problems*. Springer (New York 2003).

• L. Han, A. Tiwari, K. Camlibel, and J. S. Pang. Convergence of time-stepping schemes for passive and extended linear complementarity systems. 47 (2009) 1974-1985.

• L. Han, K. Camlibel, J. S. Pang, and W. P. M. H. Heemels. Linear-quadratic optimal control with Lipschitz state and costate trajectories: Existence and a unified numerical scheme. *Numerische Mathematik*, submitted December 2009.

• J. S. Pang and D. E. Stewart. Differential variational inequalities. *Mathematical Programming, Series A* 113 (2008) 345-424.

• Many more ...

Stability/sensitivity of parametric variational inequalities

Nguyen Dong Yen[1]

This mini-course has 4 lectures.

Lecture 1. Parametric variational inequalities: affine problems. Applications to quadratic programming and vector optimization.

Lecture 2. Hölder continuity of solutions to a parametric variational inequality.

Lecture 3. Lipschitz continuity of solutions of variational inequalities with a parametric polyhedral constraint. Applications to the traffic equilibrium problems.

Lecture 4. Generalizations and further applications (generalized variational inequalities in uniformly convex Banach spaces, equilibrium problems, vector variational inequalities, variational systems,…).

References:

[1] M. Ait Mansour and L. Scrimali, Hölder continuity of solutions to elastic traffic network models. Journal of Global Optimization 40 (2008), 175-184.

[2] L. Q. Anh and P. Q. Khanh, Uniqueness and Hölder continuity of the solution to multivalued equilibrium problems in metric spaces, Journal of Global Optimization 37 (2007), 449-465.

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[3] A. Barbagallo and M.-G. Annamaria, Continuity of solutions for parametric variational inequalities in Banach space, Journal of Mathematical Analysis and Applications 351 (2009), 707-720.

[4] R. W. Cottle, J.-S. Pang and R. E. Stone, The Linear Complementarity Problem, Academic Press, New York, 1992.

[5] P. Q. Khanh and D. T. Luc, Stability of solutions in parametric variational relation problems, Set-Valued and Variational Analysis 16 (2008), 1015-1035.

[6] G. M. Lee, N. N. Tam and N. D. Yen, Quadratic Programming and Affine Variational Inequalities: A Qualitative Study, Springer Verlag, New York, 2005.

[7] S. M. Robinson, Generalized equations and their solutions, Part I: Basic theory, Mathematical Programming Study 10 (1979), 128-141.

[8] N. D. Yen, Hölder continuity of solutions to a parametric variational inequality, Applied Mathematics and Optimization 31 (1995), 245-255.

[9] N. D. Yen, Lipschitz continuity of solutions of variational inequalities with a parametric polyhedral constraint, Mathematics of Operations Research 20 (1995), 695-708.

[10] N. D. Yen and J.-C. Yao, Monotone affine vector variational inequalities, preprint, 2009 (submitted to Optimization).

ABSTRACTS OF TALKS OF PARTICIPANTS

Stability of generalized monotone maps

Phan Thanh An[1]

We show that some well-known kinds of generalized monotone maps are not stable with respect to the property they have to keep during the generalization. Then the so-called s-quasimonotone maps are introduced and some stability properties of these maps are presented.

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Semicontinuity of the solutions set of parametric vector quasiequilibrium problem

Lam Quoc Anh[1] and Nguyen Van Hung[2]

Let X, Y and Λ be Hausdorff topological vector spaces. Let $A \subseteq X$ be nonempty. Let $K : A \times \Lambda \to 2^A$, $C : A \times \Lambda \to 2^Y$ be multifunctions and $f : A \times A \times \Lambda \to Y$ be a mapping. Assume that the values of C are closed with nonempty interiors different from Y. For $\lambda \in \Lambda$ consider the following parametric quasiequilibrium problem:

(QPVEP) Find $\bar{x} \in K(\bar{x}, \lambda)$ such that for all $y \in K(\bar{x}, \lambda)$,

$$f(\bar{x}, y, \lambda) \notin -\operatorname{int} C(\bar{x}, \lambda).$$

We establish sufficient conditions for the solution map to be lower, upper continuous, or continuous. Our results are new or include as special cases recent existing results. Examples are provided for the illustration purpose.

Keywords: Parametric vector quasiequilibrium problems, solution map, lower semicontinuity, upper semicontinuity, continuity, generalized concavity.

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Subdifferential necessary conditions for generalized-order optimal solutions in constrained set-valued optimization

Truong Quang Bao[1]

This talk concerns new *subdifferential* necessary conditions for fully localized optimal solutions to constrained set-valued optimization problems

$$\Theta\text{-minimize } F(x) \text{ subject to } x \in \Omega,$$

where $F : X \to Z$ is a set-valued mapping between infinite-dimensional Banach spaces, $\Omega \subset X$ is a geometric constraint, $\Theta \subset Z$ is an ordering set containing the origin, and Θ-minimization is understood in the sense of generalized order optimality from definition 5.53 in the book "Variational Analysis and Generalized Differentiation II: Applications" by B. Mordukhovich. Note that the ordering set Θ is not generally assumed to have either the convexity property or the nonempty interiority condition, and that the generalized order generated by Θ covers conventional notions of optimality in vector optimization and is induced by the concept of set extremality. Our method mainly bases on advanced tools of variational analysis and generalized differentiation. We also provide necessary conditions for *set-valued optimization problems with equilibrium constraints* and compairisons between them and many known necessary results in literature.

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Relationships between Robinson metric regularity and Lipschitz-like behavior of implicit multifunctions

Nguyen Huy Chieu[1], J.-C. Yao[2] and Nguyen Dong Yen[3]

By constructing some suitable examples, Jeyakumar and Yen [Solution stability of nonsmooth continuous systems with applications to cone-constrained optimization, SIAM J. Optim. 14 (2004), 1106-1127] have shown that the Robinson metric regularity (Rmr) and the Lipschitz-like property (Llp) of implicit multifunctions are not equivalent. In this talk, relationships between the two properties of implicit multifunctions are clarified.

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Sufficient conditions for pseudo-Lipschitz property in convex semi-infinite vector optimization problems

Thai Doan Chuong[1] and Jen-Chih Yao[2]

This talk is devoted to the study of the pseudo-Lipschitz property of the efficient (Pareto) solution map for the perturbed convex semi-infinite vector optimization problem (CSVO). We establish sufficient conditions for the pseudo-Lipschitz property of the efficient solution map of (CSVO) under continuous perturbations of the right-hand side of the constraints and functional perturbations of the objective function.

Key Words: Stability, semi-infinite vector optimization, Pareto solution map, pseudo-Lipschitz property.

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A brief tour of optimality conditions in convex programming

Anulekha Dhara[1] **and Joydeep Dutta**[2]

In this detailed survey, we look into the existing approaches to study the optimality conditions for convex programming problems. By a *convex programming problem* we simply mean the problem of minmizing a convex function over a convex set. More precisely we are concerned with the following problem

$$(CP) \quad \min f(x) \text{ subject to } x \in C,$$

where $f:\mathbb{R}^n \to \mathbb{R}$ is a convex function and C is a convex set, though in most cases, the set C is defined by convex inequalities and affine inequalities as

$$C = \left\{ x \in X : g_i(x) \le 0, \forall\, i = 1,2,\dots,m \text{ and } h_j(x) = 0, \forall j = 1,2,\dots,l \right\},$$

where $g_i:\mathbb{R}^n \to \mathbb{R}, i = 1,2,\dots,m$ are convex functions and $h_j:\mathbb{R}^n \to \mathbb{R}, j = 1,2,\dots,l$ are affine functions. As mentioned earlier, we are interested in studying the Karush-Kuhn-Tucker (KKT) conditions which is stated below for nonsmooth convex programming problem.

Theorem 1. *Consider the problem* (CP) *with* C *defined by convex inequalities. Assume certain constraint qualification holds. Then* $\bar{x} \in \mathbb{R}^n$ *is a minimizer of* (CP) *if and only if there exist* $\lambda_i \ge 0, i = 1,2,\dots,m$ *such that*

$$0 \in \partial f(\bar{x}) + \sum_{i=1}^{m} \lambda_i \partial g_i(\bar{x})$$

along with $\lambda_i g_i(\bar{x}) = 0, i = 1,2,\dots,m$.

The multipliers λ_i are nothing but the *Lagrange multipliers* for (CP). Observe that in the above theorem we have assumed the *constraint*

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qualification. These are basically the conditions which the constraints satisfy in order to ensure that the multiplier associated with the subdifferential of the objective function is non-zero and hence can be normalized to one. In absence of constraint qualification, the KKT conditions need not hold. A lot of works hase been done in this respect in the form of sequential optimality conditions by Thibault [5] and, Jeyakumar and his collaborators [2,3]. To the best of our knowledge, the fist step in this direction was taken by Ben-Tal, Ben-Israel and Zlobec [1], where the optimality conditions were established in terms of the direction sets for the smooth scenario. This work was extended by Wolkowicz [6] to nonsmooth scenario. Above we mentioned that in most cases, the feasible set C is expressed as convex inequalities. But recently in 2010, Lasserre [4] studed (CP) where the feasible set C is defined by nonconvex smooth inequalities and obtained the KKT conditions under some conditions similar to constraint qualification. His work highlights that it is the convexity of the feasible set that is important to derive the KKT conditions rather than the convexity of the constraint functions. In this paper we also present examples where ever possible for the better understanding of the resuls. The work is still in progress. We shall also be looking into some important classes of convex programming problems like semin-infinite programming, conic programming and semi-definite programming problems. Further we shall study the approximate optimality of convex programming problem.

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Common fixed points of non-self mappings in metrically convex spaces

Javid Ali[1]

In this paper, we extend the notions of reciprocal continuity and C_q-commutativity to nonself setting besides observing equivalence between compatibility and ϕ-compatibility, and utilize the same to obtain some resuls on coincidence and common fixed points for two pairs of nonself mappings in metrically convex metric spaces. As an application of our main result, we also prove a common fixed point theorem in Banach spaces besides furnishing several illistrative examples.

Keywords: Common fixed point, reciprocally continuous mappings, compatibility and C_q-commuting mappings.

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An equivalent definition for the backwards Itô integral

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In this paper, we give an equivalent definition of backwards Itô integral that considers a full division on a compact interval $[a,b]$.

Keywords: McShane backwards Itô integral, backwards Itô integral, *M*-integral.

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Some remarks on the structure of the solution sets of affine vector variational problem on noncompact set

Nguyen Song Ha[1] **and Ta Duy Phuong**[2]

In this talk, by analyzing some examples, we give some remarks on the efficient and weakly efficient sets of affine vector variational problem on noncompact convex set.

Keywords: Affine vector variational problem, efficient set, weakly efficient set, structure of solution set.

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Continuous selections, collectively fixed points and weakly T-KKM theorems in GFC-spaces

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We prove theorems on continuous selections, collectively fixed points, collectively coincidence points, weakly T-KKM mappings and minimax inequalities in GFC-spaces. Each of them is demonstrated by using its preceding assertions. Our results contain a number of existing ones in the recent literature.

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Stability of Pareto-Nash equilibriums of multi-objective games

Le Minh Luu[1] and <u>Tran Trinh Minh Son</u>[2]

This paper is concerned with stability properties of Pareto-Nash equilibriums of multi-objective games. We establish sufficient conditions for the semicontinuity of solution maps of these problems. We also propose and consider well-posedness notions for these games.

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Tangential extremal principle and applications

Boris Mordukhovich[1] **and** **Phan Minh Hung**[2]

Extremal principle has played an important role in variational analysis. By many authors, it is considered a counterpart of the classical separation theorem for convex sets in functional analysis. For that reason, extremal principle has been widely used in many applications. In this work, we study the extremal principle for cones based on its very special structures. Later, we derive the extremal principle for tangent cone and the fuzzy sum rule for Frechet subdifferentials. The results obtained are used in many applications to optimization problems, expecially in deriving necessary conditions for semi-infinite programs and multiobjective optimizations.

Keywords: Variational analysis and optimization, extremal principle, contigent cone, semi-infinite programming, conical hull intersection property (CHIP), strong CHIP.

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Constraint qualification and optimality conditions in nonlinear semi-infinite and infinite programming

Boris Mordukhovich[1] and Tran Thai An Nghia[2]

The paper concerns the study of new classes of optimization problems of the so-called *infinite programming* that are generally defined on infinite-dimensional spaces of decision variables and contain *infinitely many* of equality and inequality constraints. These problems reduce to *semi-infinite programs* in the case of finite-dimensional spaces of decision variables. We introduce a new extension of the well-known Mangasarian-Fromovitz constraint qualification to these infinite programs. Under this condition, we establish some upper estimates for the normal cone of the feasible set by using advanced tools of variational analysis and generalized differentiation. A crucial part of our analysis addresses necessary optimality conditions for semi-infinite and infinite programs. The results obtained are new not only for the classes of infinite programs under consideration but also for their semi-infinite counterparts.

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College mathematical readiness of the senior high school students in district I of Davao city

Melanie Joyno Orig[1]

The purpose of this study is to determine the level of mathematical proficiency of the senior high schools students enrolled in the public schools of District I in Davao City. It also sought to determine the level of readiness of the students for college mathematics. The students were given the mathematics achievement test where the contents include *Number Sense, Geometry, Probability and Statistics, Algebra and Functions.* The findings of the study were used to come up with a bridging program sponsored by the University of Mindanao as part of its community extension to help the incoming freshmen college students prepare for college mathematics.

The Level of College Mathematical Readiness of High School Students in the Public Schools of District I in Davao City

Public School	**Mean Score**	**Descriptive Equivalent**
Catalunan Grande National High School	17.45	Average
Gov. V. Duterte National High School	20.21	Average
Maa National High School	15.37	Below Average
Erico T. Nograles National High School	15.75	Below Average
Mabini National High School	17.09	Average
Catalunan Pequeno National High School	17.37	Average
Davao City National High School	24.08	Very Good
Daniel R. Aguinaldo National High School	22.99	Very Good
Sta Ana National High School	15.92	Below Average
Over-all Mean Score	**18.47**	**Average**

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On existence and convergence of best proximity pair theorems

G. Sankara Raju Kosuru[1]

Fixed point theory has applications in almost all branches of mathematics including Game theory, Differential equations, Optimization theory, Mathematical economics etc. The necessary condition, for a map $T: A \to B$ to admit a fixed point, is $A \cap B \neq \varnothing$. For a map, $T: A \to B$, where A and B are nonempty disjoint subsets of a metric space, we aim to find an $x \in A$ such that $d(x,Tx) \leq d(a,Ta)$ for all $a \in A$. We consider a self map T defined on the union of subsets A and B of a Banach space, satisfying $TA \subseteq B$ and $TB \subseteq A$. We give sufficient conditions for the existence of a best proximity pair (that is $(x,y) \in A \times B$ such that $d(x,Tx) = d(y,Ty) = dist(A,B)$ for

(i) relatively nonexpansive mappings (*i.e.*, $d(Tx,Ty) \leq d(x,y)$ for all $x \in A$ and $y \in B$).

(ii) cyclic contractions (*i.e.*, there exists $k < 1$ such that $d(Tx,Ty) \leq kd(x,y) + (1-k)dist(A,B)$ for all $x \in A$ and $y \in B$).

We give Krasnoselskii type of convergence for cyclic contractions. Also we give existence of fixed points for relative nonexpansive mappings and cyclic contractions of the type $TA \subseteq A$ and $TB \subseteq B$.

Finally we give an application of the above results to asystem of differential equations,

(1) $\quad y' = f(x,y,z),\ y(x_0) = y_0$ and $z' = g(x,y,z),\ z(x_0) = z_0$.

We give the existence of an optimal solution (in some sense), when the system (1) does not admit any solution.

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Mixed Variational Inequalities: Regularized Solutions and Convergence Rates

Nguyen Thi Thu Thuy[1] **and Nguyen Buong**[2]

Variational inequality problems appear in many fields of applied mathematics such as convex programming, nonlinear equations, equilibrium models in economics and engineering. Therefore, methods for solving variational inequalities and related problems have wide applications. These problems are considered in both finite and infinite-dimensional spaces. In this talk, we consider the problem of solving the mixed variational inequality:

For a given $f \in X^*$, find an element $x_0 \in X$ such that

$$\langle A(x_0) - f, x - x_0 \rangle + \varphi(x) - \varphi(x_0) \geq 0, \quad \forall x \in X,$$

where X is a real reflexive Banach space with its dual space X^*, $A: X \to X^*$ is a monotone bounded hemicontinuous operator with $D(A) = X$ and $\varphi: X \to \mathbb{R}$ is a properly convex lower semicontinuous functional. We study a regularization method for ill-posed inverse-strongly monotone mixed variational inequalities. The convergence rates of the regularized solution in X and in connection with finite-dimensional approximations of X are estimated for a priori choice as well as for a posteriori choice of regularization parameters that is based upon the generalized discrepancy principle. An illustrative example and numerical results are presented.

Keywords: Monotone mixed variational inequality, inverse-strongly monotone, regularization, convergence rate.

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