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Glossary of Notation

Operations and Symbols

| | |
|-------------------------------------------------|-------------------------------------------------------------------------|
| $:=$ and $=:$ | equal by definition |
| \equiv | identically equal |
| $*$ | indication of some dual/adjoint/polar operation |
| $\langle \cdot, \cdot \rangle$ | canonical pairing between space X and its topological dual X^* |
| $x \rightarrow \bar{x}$ | x converges to \bar{x} strongly (by norm) |
| $x \xrightarrow{w} \bar{x}$ | x converges to \bar{x} weakly (in weak topology) |
| $x \xrightarrow{w^*} \bar{x}$ | x converges to \bar{x} weak* (in weak* topology) |
| $x \xrightarrow{\Omega} \bar{x}$ | x converges to \bar{x} with $x \in \Omega$ |
| \liminf | lower limit for real numbers |
| \limsup | upper limit for real numbers |
| Lim inf | lower/inner limit for set-valued mappings |
| Lim sup | upper/outer limit for set-valued mappings |
| $\dim X$ and $\text{codim } X$ | dimension and codimension of X , respectively |
| \prec | preference relation |
| $\ \cdot \ $ or $ \cdot $ or $ \cdot $ | norms |
| $\text{haus}(\Omega_1, \Omega_2)$ | Pompiou-Hausdorff distance between sets |
| $\text{lip } F(\bar{x}, \bar{y})$ | exact Lipschitzian bound of F around (\bar{x}, \bar{y}) |
| $\text{reg } F(\bar{x}, \bar{y})$ | exact metric regularity bound of F around (\bar{x}, \bar{y}) |
| $\text{cov } F(\bar{x}, \bar{y})$ | exact covering/linear openness bound of F around (\bar{x}, \bar{y}) |
| $\text{rad } F(\bar{x}, \bar{y})$ | radius of metric regularity of F around (\bar{x}, \bar{y}) |
| \triangle | end of proof |

Spaces

| | |
|----------------------------------------------|----------------------------------------------------------------------|
| $\mathbb{R} := (-\infty, \infty)$ | real line |
| $\overline{\mathbb{R}} := [-\infty, \infty]$ | extended real line |
| \mathbb{R}^n | n -dimensional Euclidean space |
| \mathbb{R}_+^n and \mathbb{R}_-^n | nonnegative and nonpositive orthant of \mathbb{R}^n , respectively |

| | |
|-----------------------------------------|---------------------------------------------------------------------------------------------|
| $\mathcal{C}([a, b]; X)$ | space of X -valued continuous mappings with the supremum norm on $[a, b]$ |
| $\mathcal{C}(K)$ | space of continuous functions on the compact set K |
| $\mathcal{C}[0, \omega_1]$ | continuous functions on $[0, \omega_1]$, where ω_1 is the first uncountable ordinal |
| \mathcal{C}_0 | continuous functions with compact supports |
| $\mathcal{C}^k, 1 \leq k \leq \infty,$ | k times differentiable functions with all continuous derivatives |
| $\mathcal{C}^{1,1}$ | continuously differentiable functions with Lipschitzian derivatives |
| $L^p([a, b]; X), 1 \leq p \leq \infty,$ | standard Lebesgue spaces of X -valued mappings |
| $W^{1,p}$ and H^p | standard Sobolev spaces |
| \mathcal{M} and \mathcal{M}_b | measure spaces (dual to spaces of continuous functions) |
| BV | functions of bounded variation |
| c | space of real number sequences with the supremum norm |
| c_0 | subspace of c with sequences converging to zero |
| $\ell^p, 1 \leq p \leq \infty,$ | sequences of real numbers with standard p -norms |

Sets

| | |
|---------------------------------------------------------------|--------------------------------------------------------------------------|
| \emptyset | empty set |
| \mathbb{N} | set of natural numbers |
| $B_r(x)$ | ball centered at x with radius r |
| \mathbb{B}_X | closed unit ball of space X |
| \mathbb{B} and \mathbb{B}^* | closed unit balls of the space and duals space in question |
| S and S^* | unit spheres of the space and dual space in question |
| $\text{int } \Omega$ and $\text{ri } \Omega$ | interior and relative interior, respectively |
| $\text{cl } \Omega$ and $\text{cl}^* \Omega$ | closure and weak* topological closure, respectively |
| $\text{bd } \Omega$ or $\partial \Omega$ | set boundary |
| $\text{co } \Omega$ and $\text{clco } \Omega$ | convex hull and closed convex hull, respectively |
| $\text{cone } \Omega$ | conic hull |
| $\text{aff } \Omega$ and $\overline{\text{aff } \Omega}$ | affine hull and closed affine hull, respectively |
| $\text{mes } \Omega$ or $\mathcal{L}^n(\Omega)$ | Lebesgue (n -dimensional) measure |
| $\Pi(x; \Omega)$ | projection of x to Ω |
| $T(\bar{x}; \Omega)$ | contingent cone to Ω at \bar{x} |
| $T_W(\bar{x}; \Omega)$ | weak contingent cone to Ω at \bar{x} |
| $T_C(\bar{x}; \Omega)$ | Clarke tangent cone to Ω at \bar{x} |
| $N(\bar{x}; \Omega)$ | basic/limiting normal cone to Ω at \bar{x} |
| $N_+(\bar{x}; \Omega(\bar{y}))$ | extended limiting normal cone to $\Omega(\bar{y})$ at \bar{x} |
| $\widehat{N}(\bar{x}; \Omega)$ | prenormal cone or Fréchet normal cone to Ω at \bar{x} |
| $N_C(\bar{x}; \Omega)$ | Clarke normal cone to Ω at \bar{x} |
| $N_G(\bar{x}; \Omega)$ and $\widetilde{N}_G(\bar{x}; \Omega)$ | approximate G -normal cone and its nucleus to Ω at \bar{x} |

| | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| $N_P(\bar{x}; \Omega)$ | proximal normal cone to Ω at \bar{x} |
| $\widehat{N}_\varepsilon(\bar{x}; \Omega)$ | sets of ε -normals to Ω at \bar{x} |
| $S_\varepsilon(\bar{x}; \Omega)$ | ε -support to Ω at \bar{x} |
| Functions | |
| $\delta(\cdot; \Omega)$ | set indicator function |
| $\text{dist}(\cdot; \Omega)$ or $d_\Omega(\cdot)$ | distance function |
| $\rho(x, y) := \text{dist}(y; F(x))$ | extended distance function |
| $\text{dom } \varphi$ | domain of $\varphi: X \rightarrow \overline{\mathbb{R}}$ |
| $\text{epi } \varphi$, $\text{hypo } \varphi$, and $\text{gph } \varphi$ | epigraph, hypergraph, and graph of φ , respectively |
| $x \xrightarrow{\varphi} \bar{x}$ | $x \rightarrow \bar{x}$ with $\varphi(x) \rightarrow \varphi(\bar{x})$ |
| \mathcal{H} | Hamiltonian function in optimal control |
| H | Hamilton-Pontryagin function in optimal control |
| L | Lagrangian function in optimization |
| L_Ω | essential Lagrangian relative to Ω |
| $\tau(F; h)$ | averaged modulus of continuity |
| $\varphi'(\bar{x})$ or $\nabla\varphi(\bar{x})$ | Fréchet derivative/gradient of φ at \bar{x} |
| $\varphi'_\beta(\bar{x})$ or $\nabla_\beta\varphi(\bar{x})$ | derivative/gradient of φ at \bar{x} with respect to some bornology |
| $ \nabla\varphi (\bar{x})$ | (strong) slope of φ at \bar{x} |
| $\varphi'(\bar{x}; v)$ | classical directional derivative of φ at \bar{x} in direction v |
| $\varphi^\circ(\bar{x}; v)$ and $\varphi^\uparrow(\bar{x}; v)$ | generalized directional derivative and subderivative of φ |
| $d^-\varphi(\bar{x}; v)$ and $d^+\varphi(\bar{x}; v)$ | Dini-Hadamard lower and upper directional derivative of φ |
| $\partial\varphi(\bar{x})$ | basic/limiting subdifferential of φ at \bar{x} |
| $\partial^+\varphi(\bar{x})$ | upper subdifferential of φ at \bar{x} |
| $\partial^0\varphi(\bar{x})$ | symmetric subdifferential of φ at \bar{x} |
| $\partial_{\geq}\varphi(\bar{x})$ | right-sided subdifferential of φ at \bar{x} |
| $\partial^\infty\varphi(\bar{x})$ | singular subdifferential of φ at \bar{x} |
| $\widehat{\partial}\varphi(\bar{x})$ and $\widehat{\partial}^+\varphi(\bar{x})$ | Fréchet subdifferential and upper subdifferential of φ at \bar{x} , respectively |
| $\partial_A\varphi(\bar{x})$ and $\partial_G\varphi(\bar{x})$ | approximate A-subdifferential and G-subdifferential of φ at \bar{x} |
| $\partial_C\varphi(\bar{x})$ | Clarke subdifferential/generalized gradient of φ at \bar{x} |
| $\partial_\beta\varphi(\bar{x})$ | viscosity (bornological) β -subdifferential of φ at \bar{x} |
| $\partial_P\varphi(\bar{x})$ | proximal subdifferential of φ at \bar{x} |
| $\widehat{\partial}_\varepsilon\varphi(\bar{x})$, $\widehat{\partial}_{a\varepsilon}\varphi(\bar{x})$, and $\widehat{\partial}_{g\varepsilon}\varphi(\bar{x})$ | Fréchet-type ε -subdifferentials of φ at \bar{x} |
| $\partial_\varepsilon^-\varphi(\bar{x})$ | Dini ε -subdifferential of φ at \bar{x} |
| $\nabla^2\varphi(\bar{x})$ | classical Hessian (matrix of second derivatives in \mathbb{R}^n) of φ at \bar{x} |
| $\partial^2\varphi$, $\partial_N^2\varphi$, and $\partial_M^2\varphi$ | second-order subdifferentials (generalized Hessians) of φ |

Mappings

| | |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| $f: X \rightarrow Y$ | single-valued mappings from X to Y |
| $F: X \rightrightarrows Y$ | set-valued mappings from X to Y |
| $\text{dom } F$ | domain of F |
| $\text{rge } F$ | range of F |
| $\text{gph } F$ | graph of F |
| $\ker F$ | kernel of F |
| $F^{-1}: Y \rightrightarrows X$ | inverse mapping to $F: X \rightrightarrows Y$ |
| $F(\Omega)$ and $F^{-1}(\Omega)$ | image and inverse image/preimage of Ω under F |
| $F \circ G$ | composition of mappings |
| $F \overset{h}{\circ} G$ | h -composition of mappings |
| $\Delta(\cdot; \Omega)$ | set indicator mapping |
| Ω_ρ | set enlargement mapping |
| E_φ | epigraphical mapping |
| $\mathcal{E}(f, \Theta)$ | generalized epigraph of $f: X \rightarrow Y$ with respect to $\Theta \subset Y$ |
| $DF(\bar{x}, \bar{y})$ | graphical/contingent derivative of F at $(\bar{x}, \bar{y}) \in \text{gph } F$ |
| $D^*F(\bar{x}, \bar{y})$ | (basic) coderivative of F at $(\bar{x}, \bar{y}) \in \text{gph } F$ |
| $D_N^*F(\bar{x}, \bar{y})$ | normal coderivative of F at $(\bar{x}, \bar{y}) \in \text{gph } F$ |
| $D_M^*F(\bar{x}, \bar{y})$ and $\tilde{D}_M^*F(\bar{x}, \bar{y})$ | mixed and reversed mixed coderivative of F at (\bar{x}, \bar{y}) , respectively |
| $\widehat{D}^*F(\bar{x}, \bar{y})$ and $\widehat{D}_\varepsilon^*F(\bar{x}, \bar{y})$ | Fréchet coderivative and ε -coderivative of F at (\bar{x}, \bar{y}) , respectively |
| $Jf(\bar{x})$ | generalized Jacobian of f at \bar{x} |
| $\Lambda f(\bar{x})$ | derivate container of f at \bar{x} |

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