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Algebraic and Geometric Methods of Analysis

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LIST OF TOPICS

- Algebraic methods in geometry
- Differential geometry in the large
- Geometry and topology of differentiable manifolds
- General and algebraic topology
- Dynamical systems and their applications
- Geometric problems in mathematical analysis
- Geometric and topological methods in natural sciences

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ІНТЕРНАЦІОНАЛЬНИЙ
ЦЕНТР СПІВРОБІТНИЦТВА

On quotient spaces and their spaces of continuous maps

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Let $p : X \rightarrow Y$ be a factor map between topological spaces, that is p is surjective and a subset $A \subset Y$ is open if and only if $p^{-1}(A)$ is open in X .

Let $\Delta = \{p^{-1}(y) \mid y \in Y\}$ be the partition of X into the inverse images of points of Y . A continuous map $h : X \rightarrow X$ will be called a Δ -map if for each $\omega \in \Delta$ its image $h(\omega)$ is contained in some element ω' of Δ . Hence every Δ -map h induces a map $\psi(h) : Y \rightarrow Y$ making commutative the following diagram:

$$\begin{array}{ccc} X & \xrightarrow{h} & X \\ p \downarrow & & \downarrow p \\ Y & \xrightarrow{\psi(h)} & Y \end{array} \quad (1)$$

It is well known that $\psi(h)$ is continuous whenever h is so.

Let $\mathcal{E}(X, \Delta)$ be the monoid of all Δ -maps of X , and $\mathcal{E}(Y) = C(Y, Y)$ be the monoid of all continuous self-maps of Y . Let also $\mathcal{H}(X, \Delta)$ be the subgroup of $\mathcal{E}(X, \Delta)$ consisting of homeomorphisms and $\mathcal{H}(Y)$ be the group of homeomorphisms of Y .

Then the correspondence $h \mapsto \psi(h)$ is a well defined map

$$\psi : \mathcal{E}(X, \Delta) \rightarrow \mathcal{E}(Y) \quad (2)$$

being a homomorphism of monoids.

The following statement gives sufficient conditions under which ψ will be continuous with respect to compact open topologies on $\mathcal{E}(X, \Delta)$ and $\mathcal{E}(Y)$.

Lemma 1. *Let $p : X \rightarrow Y$ be a factor map having the following property:*

(K) *for every compact subset $L \subset Y$ there exists a compact subset $K \subset X$ such that $p(K) = L$.*

Then the homomorphism of monoids $\psi : \mathcal{E}(X, \Delta) \rightarrow \mathcal{E}(Y)$ is continuous with respect to compact open topologies.

Recall that a continuous map $p : X \rightarrow Y$

- is called *proper* if $p^{-1}(L)$ is compact for each compact $L \subset Y$;
- *admits local cross-sections* if for every $y \in Y$ there exists an open neighborhood V and a continuous map $f : V \rightarrow X$ such that $p \circ f = \text{id}_V$.

Corollary 2. *Suppose Y is a locally compact Hausdorff space. Then each of the following conditions implies that the map $\psi : \mathcal{E}(X, \Delta) \rightarrow \mathcal{E}(Y)$ is continuous with respect to compact open topologies:*

- (1) *p is a proper map;*
- (2) *p is an open map and admits local cross sections;*
- (3) *p is a locally trivial fibration.*

Let Y be a topological space. Say that two points $y, z \in Y$ are T_2 -disjoint (in Y) if they have disjoint neighborhoods. Denote by $\text{hcl}(y)$ the set of all $z \in Y$ that are *not* T_2 -disjoint from y . Then

$z \in \text{hcl}(y)$ if and only if each neighborhood of z intersects each neighborhood of y . We will call $\text{hcl}(y)$ the *Hausdorff closure* of y .

We will say that $y \in Y$ is a *branch point* whenever $\text{hcl}(y) \setminus y \neq \emptyset$, so there are points that are not T_2 -disjoint from y . The set of all branch points of Y will be denoted by $\text{Br}(Y)$.

Theorem 3. *Let X be a locally compact Hausdorff topological space, Y be a T_1 -space whose set $\text{Br}(Y)$ of branch points is locally finite, and $p : X \rightarrow Y$ be an open continuous and surjective map. Then for every compact $L \subset Y$ there exists a compact subset $K \subset X$ such that $p(K) = L$. In particular, due to Lemma 1, the map (2) $\psi : \mathcal{E}(X, \Delta) \rightarrow \mathcal{E}(Y)$ is continuous with respect to compact open topologies.*

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