SOME NEW MINIMAX THEOREMS

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ABSTRACT. We establish an alternative theorem and deduce some new minimax theorems extending classical results such as Fan, König and Simons theorems. Some applications will be given.

Keywords: Minimax theorem, Alternative theorem, convexlikeness, function spaces.

1. INTRODUCTION

Let X and Y be arbitrary nonempty sets and $f : X \times Y \to \mathbb{R}$ be a function. Recall that, f is said to be t-convexlike on X for some $t \in (0, 1)$, if and only if for all $x_1, x_2 \in X$, there exists $x_3 \in X$ such that $f(x_3, y) \leq tf(x_1, y) + (1 - t)f(x_2, y)$, for all $y \in Y$ and f is said to be t-concavelike on Y, if and only if for all $y_1, y_2 \in Y$, there exists $y_3 \in Y$ such that $f(x, y_3) \geq tf(x, y_1) + (1 - t)f(x, y_2)$, for all $x \in X$. We say that f is convexlike on X, a concept due to Fan, (resp. concavelike on Y) if and only if f is t-convexlike on X (resp. f is t-concavelike on Y) for every $t \in (0, 1)$. Clearly, a convex (resp. concave) function on a convex set is convexlike (resp. concavelike) but the converse is not true in general. The more general notions of infsup-convexity and supinf-concavity will be given in Definition 1 and Proposition 1. Several properties of these concepts and their uses can be found in [23, 25, 18, 8, 9, 10]. We say that f has a property (P) on X (resp. on Y) if the function $f(\cdot, y)$ (resp. $f(x, \cdot)$) has the property (P) for every $y \in Y$ (resp. for every $x \in X$). In general, the properties that concern us in this paper will be $(P) =$"boundedness", "semicontinuity", "convexity" or "generalized convexity".

The Fan minimax theorem in [12, Theorem 2] (see also [23, Theorem 11]) says that if Y is an arbitrary nonempty sets, X is a compact Hausdorff space and $f : X \times Y \to \mathbb{R}$ is a function, lower semicontinuous convexlike on X and concavelike on Y, then

$$\inf_{x \in X} \sup_{y \in Y} f(x, y) = \sup_{y \in Y} \inf_{x \in X} f(x, y). \quad (\blacksquare)$$

The Fan minimax theorem was extended by Simons in [22, Theorem 5c] (see also [23, Theorem 26]) to two-functions minimax inequality as follows. Let Y be an arbitrary nonempty sets, X is a compact Hausdorff space, $t \in (0, 1)$ and $f, g : X \times Y \to \mathbb{R}$ be two functions such that:

(i) f is t-convexlike and lower semicontinuous on X,
(ii) g is t-concavelike on Y.
(iii) $f \leq g$.

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