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A New Method for the Cancer Treatment by Hyperthermia Based on the Topological Derivative Concept

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Abstract: Hyperthermia is a non-invasive therapy, commonly used in treatment of cancer, consisting in artificially heating body tissue through electromagnetic waves by focusing the heat in cancerous cells. It is based on the observed fact that the vessels in the normal tissues dilate when heated, increasing the blood flow and consequently allowing the appropriated regulation of their temperature compared to the cancerous tissues which have a very disorganized and compact vascular structure, reducing the dissipation of the delivered heat by blood flow, such that the intra-tumoral temperature tends to increase. Thus, the applied heat may damage or even kill first the cancerous cells. Even if the cancerous cells do not die immediately, they may become more vulnerable to radiotherapy or chemotherapy, enabling such – in general aggressive – therapies to be given in smaller doses. However, one of the challenges in the hyperthermia treatment is to heat preferentially the cancerous tissue, elevating its temperature above $42°C$, while keeping the temperatures of the healthy tissue close to the normal temperature of the human body $42°C$. Several optimization methods have been proposed to maximize the heat in the diseased tissue and, at the same time, to minimize the hot spots concentrated in the healthy tissue that arise in the treatment. The regional electromagnetic hyperthermia problem is modeled by a semi-coupled system of partial differential equations. The heat equation in biologic tissues, or *bioheat equation*, is coupled with the *Helmholtz equation*. Electromagnetic waves are generated by spatially distributed antenna. This antenna produces a source in the Helmholtz equation, whose solution appears as a heat source in the bioheat equation. Therefore, the basic idea consists in finding a distribution of heat source generated by electromagnetic antenna, which is able to focus the heat into the tumor and keep the temperature under control in the healthy tissue. In particular, we are interested in the design of the support of the antenna, which leads to a topology optimization problem. Therefore, in this work we propose a new optimization method based on the topological derivative concept to find the optimum configuration for the antenna.