ON CAUCHY PROBLEMS FOR FUZZY DIFFERENTIAL EQUATIONS

D. N. GEORGIOU and I. E. KOUGIAS

Existence and uniqueness theorems are proved for Cauchy problems of second-order fuzzy differential equations.

2000 Mathematics Subject Classification: 34A30, 54A40, 26E50, 03E72.

1. Introduction. In 1972, Chang and Zadeh [2] first introduced the concept of fuzzy derivative, followed up ten years later by Dubois and Prade [5], who used the extension principle in their approach. In the mean time, Puri and Ralescu [12] used the notion of H-differentiability to extend the differential of set-valued functions to that of fuzzy functions. This led Seikkala [13] to introduce the notion of fuzzy derivative as an extension of the Hukuhara derivative and the fuzzy integral, which was the same as that proposed by Dubois and Prade [3, 4].

Naturally, the investigation of fuzzy differential and integral equations, existence and uniqueness theorems for the solutions of fuzzy initial value problems, drew upon the interest of many researchers of the fuzzy domain. See [1, 6, 7, 8, 9, 10, 11, 12, 13, 14] and the references therein.

In this paper, using the properties of fuzzy integration [8, 9], we examine the existence and uniqueness of initial value problems of second-order fuzzy differential equations:

$$x''(t) = f(t, x(t), x'(t)), \qquad x(t_0) = k_1, \qquad x'(t_0) = k_2. \tag{1.1}$$

2. Preliminaries. A nonempty subset A of $\mathbb{R}^n$ is called *convex* if and only if $(1 - k)x + ky \in A$ for every $x, y \in A$ and $k \in [0,1]$. By $P_k(\mathbb{R}^n)$, we denote the family of all nonempty compact convex subsets of $\mathbb{R}^n$.

For $A, B \in P_k(\mathbb{R}^n)$, the Hausdorff metric is defined by

$$d(A,B) = \max \left\{ \sup_{a \in A} \inf_{b \in B} \|a - b\|, \sup_{b \in B} \inf_{a \in A} \|a - b\| \right\}. \tag{2.1}$$

A *fuzzy set* in $\mathbb{R}^n$ is a function with domain $\mathbb{R}^n$ and values in $[0,1]$, that is, an element of $[0,1]^{\mathbb{R}^n}$ (see [15, 16]).

A member u of $[0,1]^{\mathbb{R}^n}$ is *contained* in a member v of $[0,1]^{\mathbb{R}^n}$ denoted by $u \leq v$ if and only if $u(x) \leq v(x)$, for every $x \in \mathbb{R}^n$ (see [15, 16]).

Let $u, v \in [0,1]^{\mathbb{R}^n}$. We define the following fuzzy sets (see [15, 16]):

(1) $u \wedge v \in [0,1]^{\mathbb{R}^n}$ by $(u \wedge v)(x) = \min\{u(x), v(x)\}$, for every $x \in \mathbb{R}^n$ (intersection);

(2) $u \vee v \in [0,1]^{\mathbb{R}^n}$ by $(u \vee v)(x) = \max\{u(x), v(x)\}$, for every $x \in \mathbb{R}^n$ (union);

(3) $u^c \in [0,1]^{\mathbb{R}^n}$ by $u^c(x) = 1 - u(x)$, for every $x \in \mathbb{R}^n$.

Let $u \in [0,1]^{\mathbb{R}^n}$, the *a-level set* is

$$
\begin{aligned}
[u]^a &= \{x \in \mathbb{R}^n : u(x) \geq a\}, \quad a \in (0,1], \\
[u]^0 &= Cl(\{x \in \mathbb{R}^n : u(x) > 0\}).
\end{aligned}
\tag{2.2}
$$

By E^n, we denote the family of all fuzzy sets $u \in [0,1]^{\mathbb{R}^n}$ (see, e.g., [12, 16]), for which

  (i) u is normal, that is, there exists an element $x_0 \in \mathbb{R}^n$ such that $u(x_0) = 1$;

 (ii) u is fuzzy convex, that is, for any $x, y \in \mathbb{R}^n$ and $k \in [0,1]$,

$$
u(kx + (1-k)y) \geq \min\{u(x), u(y)\};
\tag{2.3}
$$

 (iii) u is upper-semicontinuous;

 (iv) $[u]^0$ is compact.

Let $u \in E^n$. Then for each $a \in (0,1]$, the a-level set $[u]^a$ of u is a nonempty compact convex subset of $\mathbb{R}^n$, that is, $u \in P_k(\mathbb{R}^n)$. Also $[u]^0 \in P_k(\mathbb{R}^n)$.

Let

$$
\begin{aligned}
D &: E^n \times E^n \longrightarrow [0, \infty), \\
D(u, v) &= \sup\{d([u]^a, [v]^a) : a \in [0,1]\},
\end{aligned}
\tag{2.4}
$$

where d is the Hausdorff metric for nonempty compact convex subsets of $\mathbb{R}^n$.

It is well known that (E^n, D) is a complete metric space, but it is not locally compact.

Let $u, v \in E^n$ and let c be a positive number. The addition $u + v$ and (positive) scalar multiplication $c \cdot u$ in E^n are defined in terms of the a-level sets by

$$
[u+v]^a = [u]^a + [v]^a, \qquad [c \cdot u]^a = c[u]^a,
\tag{2.5}
$$

for every $a \in [0,1]$.

This defines a linear structure on E^n such that

$$
D(u+w, v+w) = D(u,v), \qquad D(c \cdot u, c \cdot v) = cD(u,v),
\tag{2.6}
$$

for all $u, v \in E^n$ and $c > 0$.

Let $T = [t_0, t_0 + a]$ with $a > 0$ and $x, y \in E^n$.

A mapping $f : T \to E^n$ is *differentiable* at $t \in T$ if there exists an $f'(t) \in E^n$ such that the limits

$$
\lim_{h \to 0^+} \frac{f(t+h) - f(t)}{h}, \qquad \lim_{h \to 0^+} \frac{f(t) - f(t-h)}{h}
\tag{2.7}
$$

exist and are equal to $f'(t)$.

Here the limit is taken in the metric space (E^n, D). At the endpoints of T, we consider the one-sided derivatives.

Let $f : T \to E^n$; the integral of f over T, denoted by $\int_T f(t)dt$, is defined levelwise by the equation $[\int_T f(t)dt]^a = \int_T f_a(t)dt = \{\int_T f(t)dt : f : T \to E^n$ is a measurable selection for $f_a\}$, for all $a \in (0,1]$.

We say that a mapping $f : T \to E^n$ is strongly measurable if, for all $a \in [0,1]$, the set-valued mapping $f_a : T \to P_k(\mathbb{R}^n)$ is defined by $f_a(t) = [f(t)]^a$.

If $f : T \to E^n$ is continuous, then it is integrable (see [8]).

3. Fuzzy differential equations

THEOREM 3.1. *Let $t_0 \in [a,b]$ and assume that $f : [a,b] \times E^n \times E^n \to E^n$ is continuous. Consider the initial value problem (1.1). A mapping $x : [a,b] \to E^n$ is a solution to (1.1) if and only if x, x' are continuous and satisfy the integral equation*

$$x(t) = k_2(t - t_0) + \int_{t_0}^{t} \left(\int_{t_0}^{t} f(s,x(s),x'(s))ds \right)ds + k_1. \tag{3.1}$$

PROOF. Since f is continuous, by [8, Corollary 4.1], it must be integrable. So, for

$$x''(t) = f(t,x(t),x'(t)), \quad t \in [a,b], \tag{3.2}$$

we have equivalently

$$x'(t) = \int_{t_0}^{t} f(s,x(s),x'(s))ds + x'(t_0) \tag{3.3}$$

(see [9, Lemma 3.1]). Since $x'(t_0) = k_2$, we have

$$x'(t) = \int_{t_0}^{t} f(s,x(s),x'(s))ds + k_2. \tag{3.4}$$

Thus, by [9, Lemma 3.1],

$$x(t) = \int_{t_0}^{t} \left(\int_{t_0}^{t} f(s,x(s),x'(s)ds) + k_2 \right)ds + x(t_0); \tag{3.5}$$

equivalently (see [8, Theorem 4.3]),

$$x(t) = \int_{t_0}^{t} \left(\int_{t_0}^{t} f(s,x(s),x'(s))ds \right)ds + \int_{t_0}^{t} k_2 ds + x(t_0); \tag{3.6}$$

equivalently (see [8, Example 4.1]),

$$x(t) = \int_{t_0}^{t} \left(\int_{t_0}^{t} f(s,x(s),x'(s))ds \right)ds + k_2(t - t_0) + x(t_0), \tag{3.7}$$

or

$$x(t) = \int_{t_0}^{t} \left(\int_{t_0}^{t} f(s, x(s), x'(s)) ds \right) ds + k_2(t - t_0) + k_1. \tag{3.8}$$

$\square$

EXAMPLE 3.2. The second-order linear nonhomogeneous fuzzy differential equation

$$x''(t) = q_1 x'(t) + q_2 x(t) + A(t), \tag{3.9}$$

where $x, x', A : [a, b] \to E^n$ are continuous functions and $q_1, q_2 \in \mathbb{R} \setminus \{0\}$, with the initial conditions

$$x(t_0) = k_1, \quad x'(t_0) = k_2, \quad t_0 \in [a, b], \tag{3.10}$$

is equivalent to a Volterra-type fuzzy integral equation

$$x(t) = \int_{t_0}^{t} k(t, s, x(s)) ds + g(t), \tag{3.11}$$

where $k : [a, b] \times [a, b] \times E^n \to E^n$ and $g(t) = k_2(t - t_0) + k_1$.

Indeed, by Theorem 3.1, the second-order linear fuzzy differential equation

$$x''(t) = q_1 x'(t) + q_2 x(t) + A(t), \qquad x(t_0) = k_1, \quad x'(t_0) = k_2, \quad t_0 \in [a, b], \tag{3.12}$$

is equivalent to the integral equation

$$x(t) = \int_{t_0}^{t} \left(\int_{t_0}^{t} f(s, x(s), x'(s)) ds \right) ds + g(t), \tag{3.13}$$

where $f(t, x(t), x'(t)) = q_1 x'(t) + q_2 x(t) + A(t)$ and $g(t) = k_2(t - t_0) + k_1$.

Let $k : [a, b] \times [a, b] \times E^n \to E^n$ be a map such that $k(t, s, x(s)) = \int_{t_0}^{t} f(s, x(s), x'(s)) ds$. Then the above integral equation is equivalent to the integral equation (3.11).

Thus, all the theorems on existence and uniqueness proved in [6, 11] hold true, equivalently for the fuzzy differential equation examined here.

THEOREM 3.3. *Let $f : [a, b] \times E^n \times E^n \to E^n$ be a continuous map and assume that there exists $k > 0$ such that*

$$D(f(t, x_1(t), x_2(t)), f(t, y_1(t), y_2(t))) \le kD(x_1(t), y_1(t)) \tag{3.14}$$

for all $t \in [a, b]$, $x_1, x_2, y_1, y_2 : [a, b] \to E^n$. Then the initial value problem

$$x''(t) = f(t, x(t), x'(t)), \qquad x(t_0) = k_1, \quad x'(t_0) = k_2, \quad t_0 \in [a, b], \tag{3.15}$$

has a unique solution on $[a, b]$.

PROOF.   Denote by $C(J,E^n)$ the set of all continuous mappings from J to E^n, where J is an interval in $\mathbb{R}$. We metricize $C(J,E^n)$ by setting

$$H(x,y) = \sup\{D(x(t),y(t)) : t \in J\} \tag{3.16}$$

for all $x,y \in C(J,E^n)$. The pair $(C(J,E^n),H)$ is a complete metric space (see [8]).

Now, let $(t_1,y_1(t),y_2(t)) \in [a,b] \times E^n \times E^n$ be arbitrary and let $n > 0$ be such that $n^2 k < 1$. We will show that the initial value problem

$$x''(t) = f(t,x(t),x'(t)), \qquad x(t_1) = y_1, \quad x'(t_1) = y_2, \quad t_1 \in [a,b], \tag{3.17}$$

has a unique solution on $I = [t_1, t_1 + n]$.

For $x \in C(I,E^n)$, define Gx on I by the equation

$$Gx(t) = y_2(t - t_1) + \int_{t_1}^t \left(\int_{t_1}^t f(s,x(s),x'(s))ds \right) ds + y_1. \tag{3.18}$$

Then by [8, Corollary 4.2], $Gx \in C(I,E^n)$. Furthermore, by [8, Theorem 4.3] and the Lipschitz condition on f, we have

$$
\begin{aligned}
H(Gx,Gy) &= \sup\{D(Gx(t),Gy(t)) : t \in I\} \\
&= \sup\Big\{ D\Big(\int_{t_1}^t \Big(\int_{t_1}^t f(s,x(s),x'(s))ds \Big) ds, \\
&\qquad\qquad \int_{t_1}^t \Big(\int_{t_1}^t f(s,y(s),y'(s))ds \Big) ds \Big) : t \in I \Big\} \\
&\leq \int_{t_1}^{t_1+n} \Big(\int_{t_1}^{t_1+n} D(f(s,x(s),x'(s)),f(s,y(s),y'(s)))ds \Big) ds \\
&\leq \int_{t_1}^{t_1+n} \Big(\int_{t_1}^{t_1+n} kD(x(s),y(s))ds \Big) ds \\
&\leq kn^2 H(x,y)
\end{aligned}
\tag{3.19}
$$

for all $x,y \in C(I,E^n)$. Hence, by Banach's contraction mapping theorem, G has a unique fixed point, which by Theorem 3.1 is the desired solution to problem (1.1).

Express $[a,b]$ as a union of a finite family of intervals I_k with the length of each interval less than n. The preceding paragraph guarantees the existence of a unique solution to problem (1.1) on each interval I_k. Piecing these solutions together gives us the unique solution on the whole interval $[a,b]$. $\square$

EXAMPLE 3.4.   The second-order linear nonhomogeneous differential equation

$$x''(t) = q_1 x(t) + A(t), \tag{3.20}$$

where $x,x',A \in C([a,b],E^n)$ and $q_1 \in \mathbb{R} \setminus \{0\}$, with the initial conditions (3.10), has a unique solution $x \in C([a,b],E^n)$ satisfying the initial conditions.

Let $f : [a,b] \times E^n \times E^n \to E^n$ be such that $f(t,x(t),x'(t)) = q_1 x(t) + A(t)$, $t \in T$. Clearly, the map f is continuous and

$$
\begin{aligned}
&D(f(t,x_1(t),x_2(t)),f(t,y_1(t),y_2(t))) \\
&\quad = D(q_1 x_1(t) + A(t), q_1 y_1(t) + A(t)) \\
&\quad = D(q_1 x_1(t), q_1 y_1(t)) \le |q_1| D(x_1(t),y_1(t))
\end{aligned}
\tag{3.21}
$$

for all $t \in [a,b]$.

Thus, by Theorem 3.3, the above problem has a unique solution.

THEOREM 3.5. *Let $f : T \times E^n \times E^n \to E^n$ be a continuous map and assume that there exists $k > 0$ such that*

$$
d([f(t,x(t),x'(t))]^a, [f(t,y(t),y'(t))]^a) \le k d([x(t)]^a, [y(t)]^a)
\tag{3.22}
$$

for all $a \in [0,1]$. Then the initial value problem

$$
x''(t) = f(t,x(t),x'(t)), \qquad x(t_0) = k_1, \quad x'(t_0) = k_2, \quad t_0 \in T,
\tag{3.23}
$$

has a unique solution.

PROOF. Indeed, we have

$$
\begin{aligned}
&D(f(t,x(t),x'(t)),f(t,y(t),y'(t))) \\
&\quad = \sup \{ d([f(t,x(t),x'(t))]^a, [f(t,y(t),y'(t))]^a) : a \in [0,1] \} \\
&\quad \le k \sup \{ d([x(t)]^a, [y(t)]^a) : a \in [0,1] \} \\
&\quad = k D(x(t),y(t))
\end{aligned}
\tag{3.24}
$$

for all $t \in T$ and $x,y \in E^n$.

Thus, by Theorem 3.3, the above problem has a unique solution. $\square$

EXAMPLE 3.6. Let $x,A : T \to E^n$ be continuous maps and $q > 0$. Then the initial value problem

$$
x''(t) = qx(t) + A(t), \qquad x(t_0) = k_1, \quad x'(t_0) = k_2, \quad t_0 \in T,
\tag{3.25}
$$

has a unique solution.

Let $f : T \times E^n \times E^n \to E^n$ be such that $f(t,x(t),x'(t)) = qx(t) + A(t)$, $t \in T$, and $x(t),x'(t) \in E^n$. Clearly, the map f is continuous and

$$
\begin{aligned}
&d([f(t,x(t),x'(t))]^a, [f(t,y(t),y'(t))]^a) \\
&\quad \le d([qx(t) + A(t)]^a, [qy(t) + A(t)]^a) \\
&\quad = d([qx(t)]^a + [A(t)]^a, [qy(t)]^a + [A(t)]^a) \\
&\quad = d([qx(t)]^a, [qy(t)]^a) \\
&\quad \le q d([x(t)]^a, [y(t)]^a)
\end{aligned}
\tag{3.26}
$$

for all $t \in T$, $x,y \in E^n$, and $a \in [0,1]$.

Thus the above problem has a unique solution.

References

[1] J. J. Buckley and T. Feuring, *Fuzzy differential equations*, Fuzzy Sets and Systems **110** (2000), no. 1, 43–54.

[2] S. S. L. Chang and L. A. Zadeh, *On fuzzy mapping and control*, IEEE Trans. Systems Man Cybernet. **2** (1972), 30–34.

[3] D. Dubois and H. Prade, *Towards fuzzy differential calculus. I. Integration of fuzzy mappings*, Fuzzy Sets and Systems **8** (1982), no. 1, 1–17.

[4] ———, *Towards fuzzy differential calculus. II. Integration on fuzzy intervals*, Fuzzy Sets and Systems **8** (1982), no. 2, 105–116.

[5] ———, *Towards fuzzy differential calculus. III. Differentiation*, Fuzzy Sets and Systems **8** (1982), no. 3, 225–233.

[6] D. N. Georgiou and I. E. Kougias, *On fuzzy Fredholm and Volterra integral equations*, J. Fuzzy Math. **9** (2001), no. 4, 943–951.

[7] ———, *Bounded solutions for fuzzy integral equations*, Int. J. Math. Math. Sci. **31** (2002), no. 2, 109–114.

[8] O. Kaleva, *Fuzzy differential equations*, Fuzzy Sets and Systems **24** (1987), no. 3, 301–317.

[9] ———, *The Cauchy problem for fuzzy differential equations*, Fuzzy Sets and Systems **35** (1990), no. 3, 389–396.

[10] J. Y. Park and H. K. Han, *fuzzy differential equations*, Fuzzy Sets and Systems **110** (2000), 69–77.

[11] J. Y. Park and J. U. Jeong, *A note on fuzzy integral equations*, Fuzzy Sets and Systems **108** (1999), no. 2, 193–200.

[12] M. L. Puri and D. A. Ralescu, *Differentials for fuzzy functions*, J. Math. Anal. Appl. **64** (1978), 369–380.

[13] S. Seikkala, *On the fuzzy initial value problem*, Fuzzy Sets and Systems **24** (1987), no. 3, 319–330.

[14] S. Song and C. Wu, *Existence and uniqueness of solutions to Cauchy problem of fuzzy differential equations*, Fuzzy sets and Systems **110** (2000), 55–67.

[15] L. A. Zadeh, *Fuzzy sets*, Information and Control **8** (1965), 338–353.

[16] H. J. Zimmermann, *Fuzzy Set Theory and Its Applications*, 2nd ed., Kluwer Academic publishers, Massachusetts, 1991.

D. N. Georgiou: Department of Mathematics, Faculty of Sciences, University of Patras, 26500 Patras, Greece

E-mail address: georgiou@math.upatras.gr

I. E. Kougias: Department of Accounting, School of Business Administration and Economics, Technological Educational Institute of Epirus, 48100 Preveza, Greece

E-mail address: kougias@teiep.gr

Special Issue on
Uncertainties in Nonlinear Structural Dynamics

Call for Papers

Nonlinear dynamical systems usually display high complexity. The last decades has seen a remarkable and fruitful development of nonlinear dynamics and a large number of papers have been published in all branches of science.

In modeling natural and man-made systems, it is assumed in general that the system is perfect and that all parameters of the system are known. However, real systems are usually imperfect and uncertainties are present both in system parameters and in the modeling stage. This is associated with the lack of precise knowledge of the system parameters, random or noisy external loading, operating conditions and variability in manufacturing processes, among other things. In many situations, these uncertainties are not important and may be overlooked in the mathematical modeling of the problem. However, in several situations, the uncertainties can have significant influence on the dynamic response and the stability of the system.

Uncertainties may also be found in system response, even in cases where all parameters are well established, such systems exhibiting high sensitivity to initial conditions.

This is particularly important in strongly nonlinear chaotic systems and those with fractal-basin boundaries.

Also, in many systems, unexpected interactions between different parts of the systems such as in nonideal problems may lead to complex responses.

However, the influence of uncertainties on local and global bifurcations and basins of attractions and on important engineering concepts such as reliability, safety, and robustness is not well studied in literature.

Even the definition of a random bifurcation is still an open problem in nonlinear dynamics.

This is a rather broad topic in nonlinear dynamics. So, the present special issue will be dedicated to the influence of uncertainties on structural dynamics (beams, plates, shells, frames, etc.). In these structures, the main sources of uncertainties are:

- Imperfections.
- Uncertainties in system parameters (mass, damping, and stiffness).
- Uncertainties in the external load, such as random loads (wind, earthquake, etc.)
- Sensitivity to initial conditions.
- Interaction between load and structure.

These types of uncertainties coupled to system nonlinearities may have a marked influence on the structure's response, particularly in a dynamic environment.

So it is useful to study their influence on bifurcations, stability boundaries, and basins of attraction.

It is also interesting to discuss their influence on safety factors, integrity measures, and confiability.

These topics are essential for a safe design of structures and the development of mathematically based safe (but not too conservative) design codes and methodologies. Since structural systems may be studied using both continuous and discretized models, problems involving PDEs and ODEs should be considered. There is a large scientific community working on nonlinear dynamics of structures that may contribute to this special issue.

Authors should follow the Mathematical Problems in Engineering manuscript format described at the journal site http://www.hindawi.com/journals/mpe/. Prospective authors should submit an electronic copy of their complete manuscript through the journal's Manuscript Tracking System at http://mts.hindawi.com/, according to the following timetable.

Manuscript Due	March 1, 2008
First Round of Reviews	June 1, 2008
Publication Date	September 1, 2008

Guest Editors

José Manoel Balthazar, Department of Statistics, Applied Mathematics and Computation, State University of Sao Paulo at Rio Claro(UNESP), 13500-230 Rio Claro, SP, Brazil; jmbaltha@rc.unesp.br

Paulo Batista Gonçalves, Civil Engineering Department, Catholic University (PUC-Rio), 22453-900 Rio de Janeiro, RJ, Brazil; paulo@civ.puc-rio.br

Reyolando M. R. L. F. Brasil, Department of Structural and Geotechnical Engineering, Polytechnic School, The University of São Paulo (PEF/EPUSP/USP) 05508-900 São Paulo, SP, Brazil; reyolando.brasil@poli.usp.br

Special Issue on
Short Range Phenomena: Modeling, Computational Aspects, and Applications

Call for Papers

In recent years, the mathematical formalism of impulsive systems (based on impulsive differential equations) has tried to join together the rigorous aspects from continuous systems formalism and the wide range of applications of discrete systems formalism. They were introduced to handle many evolution processes which are subject to singular short-term perturbations. Abrupt changes must be approached with mathematical and technical aspects dealing with the final evolution of such impulsive sources, whose effects are entirely transferred to the new state of the systems like transitions in quantum mechanics. Modern aspects in physics (quantum theory) and mathematics (wavelets, fractal theory) should be expedient in modeling short range phenomena and describing dynamics of perturbations and transitions in natural systems (advanced materials science) and advanced systems (optic, electronic, and quantum devices).

Thus, a special issue on all theoretical, computational, and practical aspects of modeling short range phenomena would be an opportunity of extending the research field of wavelets analysis, fractal theory, and applied mathematics (signal processing, control theory) for presenting new fundamental aspects in science and engineering. We are soliciting original high-quality research papers on topics of interest connected with modeling short range phenomena that include but are not limited to the following main topics:

- Mathematical aspects of pulse generation
- Dynamical and computational aspects of pulse measurement
- Wavelets analysis of localized space-time phenomena
- Stochastic aspects of pulses, sequences of pulses and time series

Authors should follow the Mathematical Problems in Engineering manuscript format described at the journal site http://www.hindawi.com/journals/mpe/. Prospective authors should submit an electronic copy of their complete manuscript through the journal's Manuscript Tracking System at http://mts.hindawi.com/, according to the following timetable:

Manuscript Due	June 1, 2008
First Round of Reviews	September 1, 2008
Publication Date	December 1, 2008

Guest Editors

Carlo Cattani, DiFarma, University of Salerno, Via Ponte Don Melillo, 84084 Fisciano (SA), Italy; ccattani@unisa.it

Ming Li, Department of Electronic Science & Technology, School of Information Science & Technology, East China Normal University, 3663 Zhongshan Bei Road, Shanghai 200062, China; mli@ee.ecnu.edu.cn

Cristian Toma, Faculty of Applied Sciences, Politehnica University, Hagi-Ghita 81, Bucharest Street 060032, Romania; cgtoma@physics.pub.ro