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A MATHEMATICAL MODEL FOR E-INCLUSION

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ABSTRACT

E-inclusion is a techno-social phenomenon that encompasses governmental and non-governmental activities initiated to overcome social exclusion that result from disintegration with the evolving information and knowledge based societies.

This paper presents a mathematical model for e-inclusion to develop a scientific understanding to e-inclusion and to aid e-inclusion stakeholder's decision makers in setting e-inclusion plans and strategies.

The presented model, which is a Modified Non-deterministic Finite Automata (MNFA), is competent to figure out the digital gap/s an individual/social group undergoes, and to execute e-inclusion activities needed to bring up digitally exclusive individuals and social group as an active participant in the e-society. The model is synchronizing with the dynamic behavior of the digital gaps that underline e-inclusion.

KEYWORDS: Digital Gaps, E-Inclusion, E-Exclusion Factors, E-Inclusion Model, Non-Deterministic Finite Automata

INTRODUCTION

"Social exclusion is a complex and multi-dimensional process. It involves the lack or denial of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society, whether in economic, social, cultural or political arenas. It affects both the quality of life of individuals and the equity and cohesion of society as a whole", [3].

With the emergence of ICTs, more factors contribute to digital inclusion/exclusion such as: demographic characteristics (age and gender), socio-economic status, education, income, socio-professional and employment status, physical abilities, place of residence (urban versus rural) and social embeddedness and social capital [6].

Beside the above factors, the rapid evolution of ICT that cause a radical dynamic change in life, leads to evolution of ICT dominated societies, introducing a new social exclusion factors due to what termed out as digital gaps or digital divide. The term digital divide refers to any inequalities between groups, in terms of access to, use of, information and communication technologies [9] [2]. The digital divide measures the gap between those who are empowered to substantially participate in an information and knowledge-based society, and those who are not.

Research suggests a large number of explanations for the digital divide including, but not limited to: education, income age, skills, awareness, ethnic origin, location, gender, political and cultural access; and psychological attitudes to Internet access and usage [4].

Previously, digital divide research has focused on accessibility to the internet and internet consumption. However, with more people accessing the internet, researchers are more interested in how people use the internet and how this usage impacts the cultural and socio-economic behavior.

The E-Inclusion term was introduces to refer to all activities leading to social inclusion in such societies. eEurope Advisory Group has defined e-Inclusion as follows: "e-Inclusion refers to the effective participation of individuals and communities in all dimensions of the knowledge-based society and economy through their access to ICT" [1].

While ICTs can function as exclusion factor and deepen the divides between societal groups, e-Inclusion can supports excluded groups and societies to take part in a wider ICT enabled society. To foster e-Inclusion public roles, most governments, international organizations and private actors develop general e-Inclusion policies, which are then implemented in the form of projects.

E-inclusion is considered as a key factor for future of any nation for a number of reasons. National economic development in agriculture, trading and industry is reliant on the effective deployment of ICT. The enhancement and perfection of governmental and public sector social services such as education and health is also dependent on ICT deployment.

This makes e-inclusion not only a sociology concern but also a political concern. A survey by CEDEFOP [5] has confirmed that European society is definitively moving toward a knowledge-based economy, given the higher level of qualifications required for European workers over the next years. Besides, the WISIS Agenda creates noticeable international movements towards information societies.

Consequently e-inclusion becomes an active socio-political issue for national governments and national, regional and international organizations.

E-inclusion modeling research attempts to provide a better understanding to the factors that influence and cause digital divide and the correlations of these factors, and to define metrics for measuring and bridging digital gaps.

The rest of this paper is organized as follows; section 2 explore related work, section 3 introduce the proposed e-inclusion model, section 4 discuss how the model works and finally conclusions are drown in section5.

RELATED WORK

Digital gaps exist in any society not due only to technical obstacles but there are many other factors that influencing the usage of ICT and causing digital gaps. In order to perform a more detailed analysis of these factors the concept of "e-Inclusion model" was introduced [7].

In [7] an e-inclusion digital gap model was introduced. The model was based on four gaps; Internet usage, E-Commerce usage, E-Government for Information and E-Government for Transaction. In model distinguish different steps of participation in the information society and analyze the gaps between these steps. The model assumes an ordered fulfillment of these gaps by individuals and performs a comprehensive quantitative analysis of current Eurostat data from [8].

In [10] the authors' models e-inclusion as a multi-dimensional process that constitutes access, usage and impact. The dimension of access includes network, affordability, availability and quality. The usage dimensions are autonomy, intensity and skills, and for impact dimensions are economic, employment and labor, education, health, government, and culture, communication and entertainment. To define and measure e-inclusion they propose a multi-focal *approach called* e-inclusion index which is structured into three components (dimensions of the general concept: access, usage, impact on quality of life) and into twelve sub-indexes. The main objectives of the index are to track progress in the development of ICTs in EU countries and to monitor the e-inclusion.

A methodology for attaining e-inclusion was proposed by [11], their approach includes, among others, activities like (i) identifying and localizing of latent demands; (ii) usage modeling; and (iii) proposing and developing of new solutions for bridging digital divide, comprising services, networks and low-cost terminals, new communication languages and interaction models.

All the above models and methodologies try either to evaluate digital gaps or to propose activities to bridge these digital gaps, but no mathematical model for e-inclusion/e-exclusion as social phenomena was proposed.

PROPOSED E-INCLUSION MODEL

We assume that an efficient e-inclusion model has to achieve the following:

- To figure out the digital gaps each individual/social group is suffering and to determine and apply accordingly the required set of e-inclusion activities needed for moving an individual or social group to an active participant in the e-society.
- To harmonize with the dynamic behavior of digital gaps that result from the rapid changes in ICT technologies, e-skills, applications and services.

To achieve these goals, we propose a stochastic empirical model, which is a Modified Non-deterministic Finite Automata (MNFA).

In the following paragraphs the formal mathematical definition for NFA is given, and then the Modified NFA (MNFA) that models e-inclusion is stated.

Definition: An NFA that responds to an input and moves to the next state is called NFA [12]. An NFA exhibits the following five characteristics:

- Finite set of states (Q)
- An alphabet Σ of possible input symbols.
- The transition function (δ) specifies the nature of the transition at a given state due to the input symbols.
- The initial state q_0.
- The set of final states (F).

So, formally, an NFA is a five- tuple: NFA = $(Q, \Sigma, \delta, q_0, F)$

Where

- Q is a finite set of states
- Σ is a set of input symbols
- δ is a transition function such that $\delta : Q \times \Sigma \rightarrow p(Q)$
- $q_0 \in Q$ is the initial state
- F subset of Q is a set of final states.

The Modified NFA is defined as follows:

- Finite set of states (Q)

- An alphabet Σ of possible input symbols.
- The transition function (δ) specifies the nature of the transition at a given state due to a transition algorithm that performs checks and calculations.
- The initial state q_0.
- A final state (F).

So MNFA differs from the traditional NFA in the way the transition function (δ) determines the next state, and in defining a single final state.

To show how MNFA can model e-inclusion, we introduce the following definitions and notations.

Digital Divide Gap

A digital divide gap is a lack that prohibits an individual or a social group from active participation in the e-Society. Examples of digital gaps are: Access, Internet Usage and E-skills. We denote the set of digital gaps by $Q = \{q_1, q_2, q_3, \ldots, q_n\}$

Inclusion Factors

These are the societal, economical and technical factors that characterize an inclusion status for a digital gap. For example Access digital gap might has the following inclusion factors: [20]

- Availability of access devices (desktop, laptop, pad, phone …etc).
- Affordability of Internet access prices
- Basic ICT skills (editing, email, web browsing, search engines)

We denote the set of inclusion factors for a digital gap q_i by $Y_{qi} = \{y_1, y_2, \ldots y_t\}$.

Inclusion Activities

These are activities initiated by public or private sector to facilitate gaining of inclusion factors. For example for the Access digital gap inclusion factor " Affordability of Internet access prices", the inclusion activities may include, providing access and ensuring availability of broadband access and information infrastructure, providing employment opportunities and providing individuals or segments with adequate skills to utilize ICT-based services.

We denote the set of inclusion activities corresponding to a single inclusion factor yi by $s_i=\{x_1, x_2, \ldots x_k\}$ where $x_m 1<=m<=k$, is an inclusion activity. Consequently we denote the set of inclusion activities corresponding to the set of inclusion factors Y_{qi} by S_{qi} where $S_{qi}=\{s_1,s_2,\ldots s_t\}$.

Digital Gap State

A digital gap state is a state where inclusion activities are applied to bridge the gap. That is to say, it is an element of the set $Q = \{ q_1, q_2, q_3, \ldots q_n \}$where at each q_i $1<=i<=n$, the corresponding set of inclusion activities $S_{qi}=\{s_1,s_2,\ldots s_t\}$ is applied.

Absolute Inclusion Factor Value

Inclusion factors associated with a specific digital gap may have different inclusion weights in bridging the digital gap. The total sum of these weights may accumulate to 1 or 100. We call this weight, which is a numeric value assigned by expert, the absolute inclusion factor value. For example, for Access digital gap the inclusion factors values might be: 40 for availability of access devices, 30 for affordability of Internet access prices and 30 for gaining of basic technical ICT skills.

We denote the absolute inclusion factor value for an inclusion factor y_i by $|y_i|$. Consequently, the total sum of inclusion factors absolute values for a digital gap qj is given by

$$|q_j| = \sum_{i=1}^{t} |yi| \quad (1)$$

Inclusion Factor Gained Value

In looking to an individual or social group, we may find that he\she is gaining an inclusion factor partially or fully, for example for the inclusion factor "Affordability of Internet Access Prices" an individual may have a job and income and can afford the access price, but he lacks the access infrastructure. We define this partially or fully gaining *as an inclusion factor gained value* which is a numeric value representing the weight of the gaining attributes of an inclusion factor. This value is measured relative to the absolute inclusion factor weight. For example individual gaining values of inclusion factors of Access digital gap might be: 40/40 for availability of access devices, 20/30 for affordability of Internet access prices and 10/30 for the basic technical ICT skills.

We denote the gaining value of the inclusion factor y_i by $|y'_i|$, and the total gained values by an individual /social group for a digital divide q_j by

$$|q'_j| = \sum_{i=1}^{t} |y'i| \quad (2)$$

The difference between the absolute inclusion factor value $|y_i|$, and the corresponding gained value $|y'_i|$, denoted by:

$$d_i = | y_i - y'_i| \quad (3)$$

define the gap weight to be bridged by the inclusion activity x_i

We will assume that d_i is acceptable (i.e, no need to apply inclusion activities), if

$$d_i <= \mu_i \quad (4)$$

where μ_i is a threshold defined by an expert.

Consequently

$$|q_j - q'_j| = \sum_{i=1}^{t} |yi - y'i| \quad (5)$$

defines the individual/social group total gap weight for a specific digital gap q_j

Based on the above stated theory, we will demonstrate how e-inclusion is modeled as MNFA. We interpret the MNFA five tuples as follows:

- Q is a finite set of states that encompass the initial state q_o, the digital gap states $q_1, q_2, q_3, \ldots q_n$, and the Final state F, which is the inclusion state.
- $\Sigma = \{ids, sg, S_{q1}, S_{q2}, \ldots S_{qn}\}$ is the set of input symbols, where the first two symbols *ids* and *sg* represent input to initial state, (an individual or a social group), and each of the other inputs $S_{q1}, S_{q2}, \ldots S_{qn}$ are sets of inclusion activities applied at the digital gap states $q_1, q_2, \ldots q_n$, respectively.
- $q_0 \in Q$ is the initial state where inputs are the symbols *ids* and *sg*.

- F € Q is the final state which is the inclusion state.
- δ is a transition function such that δ:Q x Σ → Q where δ operation is based on the current state;

At q_0 δ Operates as Follows

- On an input (ind/sg)
- δ checks sequentially through the digital gap states q_1, q_2, q_3, …q_n to see whether the ind/sg is suffering a digital divide
- If a digital divide is recognized at q_j 1<=j<n, then

  δ: q0 X ind/sg -------→ q_j

  else

  δ: q0 X ind/sg -------→ F

The checking for suffering a digital divide at q_j is done by examining the difference between the absolute inclusion factor value $|y_i|$, and the corresponding gained value $|y'_i|$, for each of the inclusion factors in $Y_{qi}=\{y_1,y_2,\ldots y_t\}$. If a difference $d_i = | y_i - y'_i| > \mu i$, is found then a digital divide is recognized.

At a Digital Gap State Q_j, J=1,2,…N, Δ Operates as Follows

- If j<n, then
  - A sequential check through the digital gap states q_{j+1},q_{j+2}, …q_n, is carried out to see whether the ind/sg is suffering a digital divide
  - If a digital divide is recognized at q_k j+1<=k<=n then

  δ: q_j X ind/sg -------→ q_k

  else

  δ: q_j X ind/sg --------→ F

- If j=n then
  - δ: q_j X ind/sg ----→ F

The checking for suffering a digital divide at q_j is done similar to q_0.

At the Final State F

- For each input to final state (ind/sg) a timer was set.
- When the timer reach a predefined threshold, then δ: F X (ind/sg) -------→ q_0

MODEL DISCUSSIONS

The Model Works as Follows

- When an individual or social group entered the initial state, the transition function algorithm determine the first digital gap state (out of a set of ordered digital gap states) that the individual/social group is suffering and figure out that digital gap state as the next state. If no such digital gap exists, the final inclusion state (F) is figured out as a next state.

- In a digital gap state the inclusion activities that needed to bridge the digital gap are applied, then the transition function checks whether the individual or social group is suffering a digital gap in the remaining digital gap states. If a digital divide is found that digital gap state will be figured out as the next state. If no digital divide is exist or the current state is last state in the ordered list of digital gap states, the final inclusion state (F) is figured as the next state.
- In the final inclusion state F, the transition function algorithm associates a timer variable to each individual/social group. On reaching the timer to a threshold (defined by an expert) the initial state is figured out as the next state.

Figure (1) shows the MNFA e-inclusion gap model. The model was built around three digital gaps q_1, q_2 and q_3. To handle the dynamic nature of the digital divide gaps, the number of members and their associated activities for each of the sets S_1, S_2, …S_n are assumed to be dynamic and can change after each iteration or cycle.

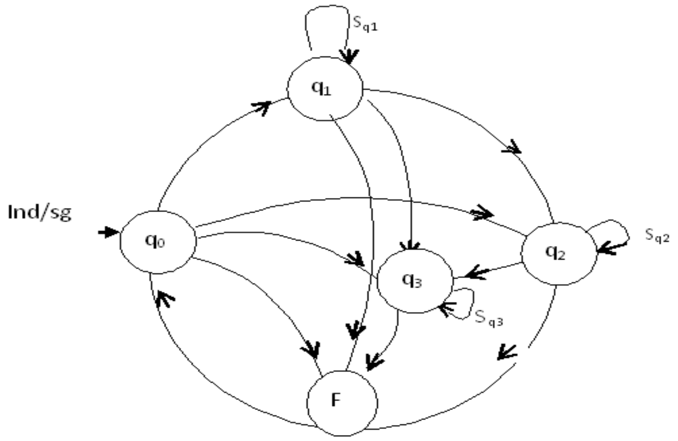

Figure 1: E-Inclusion Model

CONCLUSIONS

The developed mathematical model for e-inclusion provides a clear, formal description to the phenomenon of digital divide and e-inclusion. The model is harmonize with the dynamic behavior of both digital gaps and inclusion activities and develop a scientific understanding to e-inclusion which will lead to a better decision making and strategic planning regarding e-inclusion.

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