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Mathematical and Computer Modeling of the State of Complex Systems under the Influence of Potential Forces

By Kulshat Akanova, Assem Myrkanova, Gaukhar Abdenova & Kenzhebayeva Zhanat
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Abstract- This article considers the problem of determining critical points and areas in a system that is exposed to external forces. As a result, the system can lose its stability and go into a non-equilibrium state, and then collapse and cause various kinds of catastrophes. The study of the problem of identification and prediction of disasters is relevant, because allows you to take preventive measures to prevent them and reduce the risks of various negative scenarios. The mathematical theory of catastrophes and methods of the theory of stability find practical applications in various fields of applied mathematics, physics, mechanics, biology, as well as in economics and other sciences. The control of the bifurcation parameters of the system, under which the loss of its stability occurs, makes it possible to maintain its equilibrium state and avoid a catastrophe. As an example, the problem of determining the system deformations that arise under the action of the potential function of classical and couple stresses is given. Analytical and numerical methods for solving this problem and performing calculations using the high-level programming language Fortran, which is widely used for scientific and engineering calculations, contribute to obtaining an adequate result.

Keywords: *catastrophe, deformation, collapse, bifurcation, deformations, system stability.*

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Mathematical and Computer Modeling of the State of Complex Systems under the Influence of Potential Forces

Kulshat Akanova [α], Assem Myrkanova [σ], Gaukhar Abdenova [ρ] & Kenzhebayeva Zhanat [ω]

Abstract– This article considers the problem of determining critical points and areas in a system that is exposed to external forces. As a result, the system can lose its stability and go into a non-equilibrium state, and then collapse and cause various kinds of catastrophes. The study of the problem of identification and prediction of disasters is relevant, because allows you to take preventive measures to prevent them and reduce the risks of various negative scenarios. The mathematical theory of catastrophes and methods of the theory of stability find practical applications in various fields of applied mathematics, physics, mechanics, biology, as well as in economics and other sciences. The control of the bifurcation parameters of the system, under which the loss of its stability occurs, makes it possible to maintain its equilibrium state and avoid a catastrophe. As an example, the problem of determining the system deformations that arise under the action of the potential function of classical and couple stresses is given. Analytical and numerical methods for solving this problem and performing calculations using the high-level programming language Fortran, which is widely used for scientific and engineering calculations, contribute to obtaining an adequate result.

Keywords: catastrophe, deformation, collapse, bifurcation, deformations, system stability.

I. Introduction

An analysis of the stability of a certain system is an urgent practical problem, since its reaction even to a small perturbation of the parameters can be so strong that it will lead the system to a catastrophic state of destruction. Natural disasters and other emergencies of a natural and man-made nature are threats to the national security of the country, since their onset leads to significant material damage to the economy and loss of human lives [1].

A catastrophe is the transition of a system from a stable state with small fluctuations and damped oscillations to a state in which the amplitude of these oscillations grows and transfers the system to a new non-equilibrium state.

Methods of catastrophe theory offer tools for studying abrupt and abrupt transitions to a non-equilibrium state of a system as a result of changes in its parameters, i.e. bifurcations. The identification of the main types of bifurcations and the construction of bifurcation diagrams will make it possible to control the parameters of a dynamic system in order to increase its stability.

The mathematical theory of catastrophes arose thanks to the efforts of many scientists, is based on the theory of stability and bifurcations of dynamical systems and analyzes the critical points of a potential function.

The works of the American mathematician G. Whitney laid the foundations for the theory of singularities or singularities at points where the mathematical function is not defined or has irregular behavior [2].

The terms "catastrophe" and "catastrophe theory" were coined by the British mathematician Christopher Zieman and René Thom in the late 1960s and early 1970 s. E.K. Zieman proposed to use the term "catastrophe theory" to combine the theory of singularities, the theory of bifurcations and their applications. Singularity theory provides information about critical points for studying the onset of a "catastrophe", that is, a jump-like transition of a system from one state to another when its parameters change [3].

In his works, R. Tom gives a deep classification of seven fundamental types of catastrophes and analyzes the critical points at which the potential function loses its stable equilibrium [4].

V. I. Arnold expands the "ADE-classification" of catastrophe models, using deep connections with the theory of Lie algebra [5].

The works of the American scientist Gilmore R. (Gilmore R.) is devoted to the practical application of the theory of catastrophes in such areas of science and technology as mechanics, construction, climatology and others [6].

The issues of modeling natural disasters are considered in the work of scientists S.L. Castillo Daza and F. Naranjo Mayorga [7].

An important task in science and technology is to ensure the strength and reliability of industrial and civil

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facilities in the face of man-made and natural disasters. The task is complicated by the fact that both catastrophes can have a simultaneous impact on an engineering structure. The reason for such synergy may be their mutual influence, since natural disasters can be the primary source of a man-made disaster, and vice versa.

Deformations can lead to the loss of stability of the technical structure and to its collapse, and thus cause a man-made disaster. Reducing the negative consequences of their occurrence depends on how quickly it is possible to predict them, and then effectively use the mechanisms and tools to neutralize the negative consequences.

II. Statement of the Problem and Mathematical Model

a) *Formulation of the Problem*

Consider the solution of the problem of the state of an underground engineering structure in a rock mass, which is affected not only by ordinary (classical) stresses, but also by couple stresses (Cosserat Wednesday Cosserat). In this case, classical stresses lead to tensile-compressive and shear deformations, while couple stresses cause deformations of curvature and rotation in the system.

The state of an elastic rock mass with an engineering structure is modeled by an infinite isotropic plane with moment stresses, in which there is a hole of arbitrary shape. It is required to obtain analytical formulas for determining the components of the stress, displacement and rotation functions of the elements of the rock mass around the engineering structure in order to identify critical areas.

This complex task will consist of two stages.

First, the state of the main (zero) untouched massif is determined, which is modeled by a solid plane.

Secondly, additional components of the functions of stresses, displacements and rotation of the array, in which there is a hole of arbitrary non-circular shape, are determined.

The stress state of an elastic plane with a hole consists of the components of the main stresses of the untouched massif and the components of additional stresses due to the presence of the hole. Stress functions can be represented as a sum (1):

$$\varphi(\zeta)=\varphi^0(\zeta)+\varphi^{00}(\zeta),\psi(\zeta)=\psi^0(\zeta)+\psi^{00}(\zeta),\ P(\zeta,\bar{\zeta})=P^0(\zeta,\bar{\zeta})+P^{00}(\zeta,\bar{\zeta}) \quad (1)$$

where $\varphi^0(\zeta),\psi^0(\zeta),P^0(\zeta,\bar{\zeta})$ - stress functions of the ground state characterizing the untouched massif;

$\varphi^{00}(\zeta),\psi^{00}(\zeta),P^{00}(\zeta,\bar{\zeta})$ - stress functions of the additional stress state caused by the presence of a working;

$P^0(\zeta,\bar{\zeta})$- solution of the well-known Helmholtz equation of the form (2):

$$\Delta P+c^2P=0 \quad (2)$$

where Δ- Laplace operator, value c^2 - is the square of the modulus of the wave vector,

$$\varepsilon_x^0=\frac{1}{2G}\left[\sigma_x^0-\nu\left(\sigma_x^0+\sigma_y^0\right)\right], \quad (4)$$

where the quantities $\sigma_x^0,\sigma_y^0,\tau_{xy}^0,\tau_{yx}^0\left(\tau_{xy}^0\neq\tau_{yx}^0\right)$ and μ_x^0,μ_y^0- components, respectively, of the main ordinary and couple stresses of the untouched massif;

$\varepsilon_x^0,\varepsilon_y^0,\gamma_{yx}^0$ – components of the main deformations from ordinary stresses;

$\varphi^0(z),\psi^0(z)$– Kolosov-Muskhelishvili stress functions for rock massif [8].

Let us write in the Cartesian coordinate system the basic (zero) equations of the planar moment theory of elasticity in the case of the absence of bulk ordinary and moment forces in an untouched massif:

- equilibrium equations according to the formula (3):

$$\frac{\partial\sigma_x^0}{\partial x}+\frac{\partial\tau_{yx}^0}{\partial y}=0;\ \frac{\partial\tau_{xy}^0}{\partial x}+\frac{\partial\sigma_y^0}{\partial y}=0;\ \frac{\partial\mu_x^0}{\partial x}+\frac{\partial\mu_y^0}{\partial y}+\tau_{xy}^0-\tau_{yx}^0=0 \quad (3)$$

- Hooke's law for a medium with couple stresses according to formula (4):

$$\gamma_{xy}^0=\frac{1}{4G}\left(\tau_{xy}^0+\tau_{yx}^0\right),\ \chi_x^0=\frac{\mu_x^0}{4G},\ \chi_y^0=\frac{\mu_y^0}{4G}$$

χ_x^0,χ_y^0- components of the main deformations (curvature) from moment stresses in an intact massif;

E – Young's modulus, G – Poisson's ratio.

The deformations and the component of the rotation vector are related to the components of the displacement vector by formulas (5):

$$\varepsilon_x^0=\frac{\partial u^0}{\partial x},\ \varepsilon_x^0=\frac{\partial v^0}{\partial y},\ \gamma_{xy}^0=\frac{1}{2}\left(\frac{\partial v^0}{\partial x}+\frac{\partial u^0}{\partial y}\right),\ \chi_x^0=\frac{\partial\omega^0}{\partial x},\ \chi_y^0=\frac{\partial\omega^0}{\partial y},\ \omega^0=\frac{1}{2}\left(\frac{\partial v^0}{\partial x}-\frac{\partial u^0}{\partial y}\right) \quad (5)$$

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III. Mathematical Model and Problem Solving Methodology

To solve the problem, analytical and numerical methods are used, as well as calculations using the Fortran programming language. The choice in favor of this particular programming language is dictated by the convenience and obtaining a more accurate solution of differential equations.

Let us construct some domains S and Σ on the plane, which are described by the corresponding analytic functions of the complex variables z and ζ. Let us assign to each point ζ of the region Σ a certain point z of the region S using relation (6):

$$z = \omega(\zeta) \tag{6}$$

where $\omega(\zeta)$ is a single-valued analytic function in some domain Σ on the plane of the complex variable $\zeta = \xi + i\eta$, i is the imaginary unit ($i^2 = -1$).

If the reverse correspondence is also possible, then there is a conformal mapping or transformation of the domain S onto Σ, and vice versa [7].

If the function (6) has a simple pole at some point, then the point $z = \infty$ corresponds to the point ζ, and the function $\omega(\zeta)$ will have the form $\omega(\zeta) = \frac{c}{\zeta} + f(\zeta)$ with a holomorphic function $f(\zeta)$ (c-const). The point ζ can become a potential bifurcation point or a critical point of the problem.

In addition, a holomorphic function can be expanded in a series with any required accuracy in the form (7):

$$f(\zeta) = a_0 + \frac{a_1}{\zeta} + \frac{a_2}{\zeta^2} + \frac{a_3}{\zeta^3} + \ldots \tag{7}$$

Such a transformation allows you to display any mathematical function from the Cartesian coordinate system to the polar one. The geometric interpretation of such an operation is to map the area of an arbitrary contour onto a circle of unit radius centered at the origin, which greatly simplifies calculations.

The advantage of the proposed method is obtaining numerical results in dimensionless units.

In an untouched rock mass, only vertical displacements take place, so the main stresses have the following form (8):

$$\sigma_x^0 = \lambda\sigma_y^0 = -\lambda\gamma H,\ \tau_{xy}^0 = \tau_{yx}^0 = 0,\ \mu_x^0 = \mu_y^0 = 0 \tag{8}$$

where $\lambda = \frac{\nu}{1-\nu}$ - side pressure coefficient, γ – specific (volumetric) weight of a rock mass; H - the depth of the array point being considered. Now the main stress functions will be equal to (9):

$$\varphi^0(z) = \Gamma z = -\frac{\gamma H(1+\lambda)}{4} z,\ \psi^0(z) = \Gamma' z = -\frac{\gamma H(1-\lambda)}{2} z,\ P^0(z,\bar{z}) = 0 \tag{9}$$

where Γ, Γ' – stress distribution characteristics at infinity.

Let's construct an underground tunnel of an arbitrary transverse profile in a rock mass and find the components of ordinary and moment stresses, displacements and rotations in its vicinity. Such an array around a non-circular working is modeled under plane deformation conditions as an infinite isotropic elastic weightless plane with asymmetric stress tensors. It is weakened by a hole of some form in the plane of the complex variable z=x+iy and free from external forces and moments.

The calculation scheme of the problem is shown in Figure 1, where a non-circular hole of arbitrary shape is located in the plane of the complex variable z=x+iy.

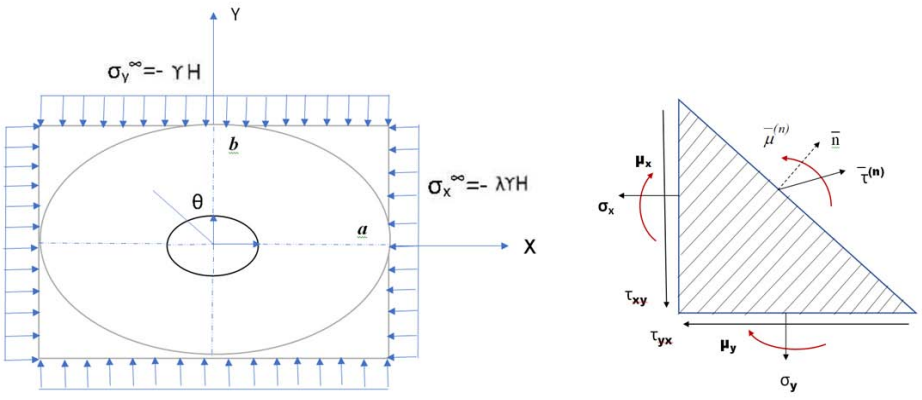

Fig. 1: Calculation Scheme of the Problem

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To solve the problem, we pass to the region of the complex variable Σ and conformally map the entire infinite region outside the hole onto the exterior of the unit circle in the variable $\zeta = \xi + i\eta = \rho e^{i\theta}$ plane using the mapping function (10):

$$z = \omega(\zeta) = R[\zeta + \varepsilon\phi(\zeta)] = R(\zeta + \varepsilon\zeta^{-1}) \qquad (10)$$

where ρ, θ are polar coordinates.
Condition (11) is required:

$$1 + \varepsilon\phi'(\zeta) \neq 0 \text{ при } |\zeta| \geq 1 \qquad (11)$$

Here $\phi(\zeta) = \sum_{1}^{N}(\alpha_n + i\beta_n)\zeta^{-n}$ $(\alpha_n, \beta_n, R - const)$,

$R = \frac{a+b}{2}, \varepsilon = \frac{a-b}{a+b}$ (*a*,*b* – semiaxes of an ellipse),

ε - small numerical parameter, is in the interval $-1 \leq \varepsilon \leq 1$ and characterizes the deviation of a given hole from a circular.

To solve the problem, initial and boundary conditions are set.

1. Initial conditions at t=0 are given by formula (12):

$$\upsilon_\rho = 0, \upsilon_\theta = 0, \omega_{\rho\theta} = 0 \qquad (12)$$

2. Boundary conditions on the contour of a unit circle at are $\rho = 1$ given by formula (13):

$$\sigma_\rho - i\tau_{\rho\theta} = 0 \ , \ \mu_\rho = 0 \qquad (13)$$

where $\upsilon_\rho, \upsilon_\theta, \omega_{\rho\theta}$ - displacement and rotation components, $\sigma_\rho, \tau_{\rho\theta}, \mu_\rho$ - stress components on the circuit.

The functions of the main stresses in the displayed area according to formula (8) will take the following form (14):

$$\varphi^\circ(\zeta) = \Gamma\omega(\zeta), \psi^\circ(\zeta) = \Gamma'\omega(\zeta), \mathrm{P}^\circ(\zeta, \bar{\zeta}) = 0 \qquad (14)$$

The additional stress functions are found from the boundary conditions and, according to the Laurent theorem, can be represented in the region outside the hole by uniformly convergent power series (15):

$$\varphi^{00}(\zeta) = a_n\zeta^{-n}, \psi^{00}(\zeta) = \sum_{0}^{\infty} b_n\zeta^{-n}, \ \mathrm{P}^{00}(\zeta, \bar{\zeta}) = \sum_{-\infty}^{\infty} p_n \mathrm{K}n(cR\rho)e^{-in\theta} \qquad (15)$$

where $\mathrm{K}n(cR\rho)$ – modified Bessel function of the second kind of the nth order of the imaginary argument (McDonald function) [10]. To find the derivatives of the function, the following well-known recursive formulas (16) were used:

$$\frac{\partial^k}{\partial\zeta^k}\left[\mathrm{K}_n(cR\rho)e^{\pm in\theta}\right] = \left(-\frac{cR}{2}\right)^k K_{n\mp k}e^{\pm i(n\mp k)\theta},$$
$$\frac{\partial^k}{\partial\bar{\zeta}^k}\left[\mathrm{K}_n(cR\rho)e^{\pm in\theta}\right] = \left(-\frac{cR}{2}\right)^k \mathrm{K}_{n\pm k}e^{\pm i(n\pm k)\theta} \qquad (16)$$

After carrying out the required transformations, the stress functions $\varphi(\zeta), \psi(\zeta)$ are obtained, which will be holomorphic from ζ outside the circle of unit radius, and the function $\mathrm{P}(\zeta, \bar{\zeta})$ will satisfy equation (17):

$$\Delta = \frac{\partial^2}{\partial\zeta^2} + \frac{\partial^2}{\partial\eta^2} = 4\frac{\partial^2}{\partial\zeta\partial\bar{\zeta}} \qquad (17)$$

$$\Delta\mathrm{P} - c^2|\omega'(\zeta)|^2\mathrm{P} = 0,$$

Potentials $\varphi(\zeta), \psi(\zeta), \mathrm{P}(\zeta, \bar{\zeta})$ outside the contour of the hole will be sought in the form of series in powers of the small parameter ε according to formula (18) and we will restrict ourselves to the zeroth and first approximations:

$$\varphi(\zeta) = \sum_{0}^{\infty}\varepsilon^n\varphi_n(\zeta), \quad \psi(\zeta) = \sum_{0}^{\infty}\varepsilon^n\psi_n(\zeta), \quad \mathrm{P}(\zeta, \bar{\zeta}) = \sum_{0}^{\infty}\varepsilon^n\mathrm{P}_n(\zeta, \bar{\zeta}) \qquad (18)$$

We expand the functions included in the boundary conditions (13) into functional series in powers of the small parameter ε according to (18) and compare the expressions with each other for its equal powers. For expansion, we also use the following well-known power series (19):

$$\frac{1}{(1+x)} = \sum_{0}^{\infty}(-1)^k x^k = 1 - x + x^2 - x^3 + \ldots \qquad (19)$$

Differentiating it, we get another power series we need (20):

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$$\frac{1}{(1+x)^2}=\sum_0^\infty(-1)^{k+1}kx^{k-1}=1-2x+3x^2-... \quad (20)$$

Also, equating the expressions with equal powers of the small parameter $\sigma^n=e^{in\theta}$, we obtain the following system for determining the solution of the Helmholtz equation - functions Pn (21):

$$\left.\begin{aligned}&\Delta P_0-c^2R^2P_0=0\\&\Delta P_1-c^2R^2P_1=c^2R^2(\phi'+\bar{\phi}')P_0\\&\Delta P_n-c^2R^2P_n=c^2R^2\left[(\phi'+\bar{\phi}')P_{n-1}+|\phi'|^2P_{n-2}\right],n\geq 2\end{aligned}\right\} \quad (21)$$

In this case, we restrict ourselves to the zero and first approximations (22)-(24):

$$\begin{aligned}&\varphi(\zeta)=\varphi_0(\zeta)+\varepsilon\varphi_1(\zeta)=\Gamma\omega(\zeta)+\sum_1^\infty a_n\zeta^{-n}=\\&=\Gamma(\zeta+\varepsilon\zeta^{-1})+[a_1^{(0)}+\varepsilon a_1^{(1)}]\zeta^{-1}+[a_3^{(0)}+\varepsilon a_3^{(1)}]\zeta^{-3}\\&=\Gamma\zeta+\frac{a_1^{(0)}}{\zeta}+\varepsilon[\frac{\Gamma}{\zeta}+\frac{a_1^{(1)}}{\zeta}+\frac{a_3^{(1)}}{\zeta^3}]\end{aligned} \quad (22)$$

$$\psi(\zeta)=\Gamma'\zeta+\frac{b_1^{(0)}}{\zeta}+\frac{b_3^{(0)}}{\zeta^3}+\varepsilon\left[\frac{\Gamma'}{\zeta}+\frac{b_1^{(1)}}{\zeta}+\frac{b_3^{(1)}}{\zeta^3}+\frac{b_5^{(1)}}{\zeta^5}\right] \quad (23)$$

$$\begin{aligned}&P\left(\zeta,\bar{\zeta}\right)=\left[p_2^{(0)}e^{2i\theta}+\bar{p}_2^{(0)}e^{-2i\theta}\right]K_2(cR\rho)+\\&+\varepsilon\left\{\Gamma'\frac{F}{1+F}\frac{c^2R^2}{6cK_1(cR)}K_2(cR\rho)sin4\theta+\right.\\&\left.+\varepsilon\left\{\left[p_2^{(1)}e^{2i\theta}+\bar{p}_2^{(1)}e^{-2i\theta}\right]K_2(cR\rho)\right.\right.\end{aligned} \quad (24)$$

where $a_n^{(0)},b_n^{(0)},p_n^{(0)}(n\geq 1)$ - zero approximation coefficients;

$a_n^{(1)},b_n^{(1)},p_n^{(1)}(n\geq 1)$ - coefficients for the first approximation.

As a result of expansion into series (18) and equating the coefficients for the same powers of a small parameter, we obtain a sequence of boundary value problems for a circular hole $(\omega=R\xi)$:

$$\left.\begin{aligned}&\varphi_0+\sigma\overline{\varphi_0'}+\overline{\psi}+\frac{m}{R}\overline{\Phi_0'}-\frac{2i}{R}\frac{\partial P_0}{\partial\bar{\sigma}}=0\\&\mathrm{Re}\left\{\frac{i}{\sigma}\left[m\overline{\Phi_0'}-2i\frac{\partial P_0}{\partial\bar{\sigma}}\right]\right\}=0\end{aligned}\right\} \quad (25)$$

$$\left.\begin{aligned}&\varphi_n+\sigma\overline{\varphi_n'}+\overline{\psi_n}+\frac{m}{R}\overline{\Phi_n'}-\frac{2i}{R}\frac{\partial P_n}{\partial\bar{\sigma}}+\varphi_{n-1}\bar{\phi}'+\overline{\varphi_{n-1}'}\phi+\overline{\psi_{n-1}}\bar{\phi}'=0\\&\mathrm{Re}\left\{\frac{i}{\sigma}\left[m\overline{\Phi_n'}-2i\frac{\partial P_n}{\partial\bar{\sigma}}\right]\right\}=0\qquad(n=1,2,3...)\end{aligned}\right\} \quad (26)$$

IV. Results and Performance Analisis

A feature of problem (24) is that, as a result of the solution, we obtain only the imaginary parts of the complex variable $\zeta=\xi+i\eta$.

1. The stress functions of the state of the array in the zeroth approximation.

In the displayed area Σ on the contour of the working at ρ=1, the components of stresses and displacements are calculated as follows:

- for the main stress state according to the formulas (27):

$$\begin{aligned}&\sigma_\rho^{(0)0}=-\frac{\gamma H}{2}\left[(1+\lambda)-(1-\lambda)\cos 2\theta\right],\\&\sigma_\theta^{(0)0}=-\frac{\gamma H}{2}\left[(1+\lambda)+(1-\lambda)\cos 2\theta\right],\\&\tau_{\rho\theta}^{(0)0}=-\frac{\gamma H}{2}(1-\lambda)\sin 2\theta\\&\tau_{\theta\rho}^{(0)0}=-\frac{\gamma H}{2}(1-\lambda)\sin 2\theta,\\&\upsilon_\rho^{(0)0}=-\frac{\gamma H\rho}{4G}\left[(1-2\nu)(1+\lambda)-(1-\lambda)\cos 2\theta\right],\\&\upsilon_\theta^{(0)0}=-\frac{\gamma H\rho}{4G}(1-\lambda)\sin 2\theta,\\&\mu_\rho^0=\mu_\theta^0=\omega_{\rho\theta}^0=0,\end{aligned} \quad (27)$$

- for an additional stress state according to formulas (28):

$$\begin{aligned}&\sigma_p^{(0)00}=\frac{\gamma H}{2}\{(1+\lambda)-(1-\lambda\cos 2\theta)\},\\&\sigma_\theta^{(0)00}=-\frac{\gamma H}{2}\left\{(1+\lambda)+\left[3-\frac{4F}{1+F}\right](1-\lambda)\cos 2\theta\right\},\\&\tau_{p\theta}^{(0)00}=\frac{\gamma H}{2}(1-\lambda)\sin 2\theta\\&\tau_{\theta_p}^{(0)00}=\frac{\gamma H}{2}\left\{1-\frac{2F}{1+F}\left(2+cR\frac{K_0(cR)}{K_1(cR)}\right)\right\}(1-\lambda)\sin 2\theta,\\&\mu_\rho^{(0)00}=0,\mu_\theta^{(0)00}=\gamma HR\frac{F}{1+F}(1-\lambda)cos2\theta\\&\upsilon_\rho^{(0)00}=-\frac{\gamma HR}{4G}\left\{(1+\lambda)-\left[3-4\nu-\frac{4(1-\nu)F}{1+F}\right](1-\lambda)cos2\theta\right\}\\&\upsilon_\theta^{(0)00}=-\frac{\gamma HR}{4G}\left\{3-4\nu-\frac{4(1-\nu)F}{1+F}\right\}(1-\lambda)sin2\theta\\&\omega_{\rho\theta}^{(0)00}=\frac{\gamma H}{8G}c^2R^2\frac{F}{1+F}(1-\lambda)sin2\theta\end{aligned} \quad (28)$$

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$$F = \frac{8(1-\nu)}{4 + c^2R^2 + 2cR[K_0(cR)/K_1(cR)]} \quad (29)$$

where

2. The stress functions of the state of the array in the first approximation.

- the components of the main stresses on the contour of the working at ρ=1 will be found by the formulas (30):

$$\sigma_\rho^{(1)0} = \frac{\gamma H(1-\lambda)}{2}\{\cos 4\theta - 1\},$$
$$\sigma_\theta^{(1)0} = -\frac{\gamma H(1-\lambda)}{2}\{\cos 4\theta - 1\},$$
$$\tau_{\rho\theta}^{(1)0} = -\frac{\gamma H(1-\lambda)}{2}\sin 4\theta, \quad (30)$$
$$\tau_{\theta\rho}^{(1)00} = -\frac{\gamma H(1-\lambda)}{2}\sin 4\theta,$$
$$\upsilon_\rho^{(1)0} = -\frac{\gamma HR}{4G}\left\{-\frac{1-\lambda}{2} + (1+\lambda)(1-2\cos 2\theta) - \frac{1-\lambda}{2}\cos 4\theta\right\},$$
$$\upsilon_\theta^{(1)0} = -\frac{\gamma HR}{4G}\left\{2(1+\lambda)(2\nu-1)\sin 2\theta + \frac{1-\lambda}{2}\sin 4\theta\right\}$$
$$\mu_\rho^{(1)0} = \mu_\theta^{(1)0} = \omega_{\rho\theta}^{(1)} = 0$$

- the components of additional stresses on the working contour at $\rho=1$ can be found by the formulas (31):

$$\sigma_\rho^{(1)00} = -\frac{\gamma H(1-\lambda)}{2}[\cos 2\theta - 1]$$
$$\sigma_\theta^{(1)00} = -\frac{\gamma H(1-\lambda)}{2} - \frac{2\gamma H(1+\lambda)}{1+F}\cos 2\theta -$$
$$-\frac{2\gamma H(1-\lambda)}{1+F}\left[\frac{3-F}{4} - \frac{4(1-\nu)R_2}{R_1}\right]\cos 4\theta \quad (31)$$
$$\tau_{\rho\theta}^{(1)00} = \frac{\gamma H(1-\lambda)}{2}\sin 4\theta \quad \tau_{\theta\rho}^{(1)00} = \tau_{\rho\theta}^{(1)00} + c^2R_1$$

$$\mu_\rho^{(1)00} = 0$$
$$\mu_\theta^{(1)00} = \frac{\gamma HR}{2}\frac{F}{1+F}\{1-\lambda+2(1+\lambda)\cos 2\theta +$$
$$+(1-\lambda)\left[1+\frac{c^2R^2}{6}\frac{K_1+K_3}{K_1}\frac{R_2}{R_1}\right]\cos 4\theta\}$$
at $R_1 = 1 + \frac{96(1-\nu)K_3}{c^2R^2[K_3+K_5]}$,
$$R_2 = \frac{K_1 - \frac{2}{cR}K_2}{K_1+K_3} + \frac{\left(\frac{24}{c^2R^2}-1\right)K_3}{K_3+K_5}, \quad (32)$$

From the formulas (27)-(32) obtained above for the main and additional stress state, it is clearly seen that the effect of moment stresses affects only the additional stress state of the mass, which consists of the classical elastic part and the part due to the influence of the new elastic constant λ included in the quantity $\frac{F}{1+F}$.

According to formulas (27) - (32), we will carry out numerical calculations using Fortran, we will build graphs with initial data that characterize the physical properties of the siltstone rock [11]:

$E = 0{,}62\cdot 10^{10}\,МПа$, ν=0.20, α=0.726, $\delta = 0.0094\,сек^{\alpha-1}$, λ=0.25, cR=3, Macdonald functions of the second kind $K_0 = 0.0347$, $K_1 = 0.0402$, $K_2 = 0.0615$, $K_3 = 0.1222$, $K_4 = 0.3059$, $K_5 = 0.9378$, $K6 = 3.4318$. The polar angle is taken in the interval $0 \le \theta \le 2\pi$.

Table 1 shows the dimensionless values of the main stresses of a solid rock mass in the zero and first approximation, calculated using formulas (25) and (26).

Table 1: Basic Stresses of a Solid Rock Mass in the Zero and First Approximation

θ, degree	$-\frac{\sigma_\rho^{(0)0}}{\gamma H}$	$-\frac{\sigma_\rho^{(1)0}}{\gamma H}$	$-\frac{\sigma_\theta^{(0)0}}{\gamma H}$	$-\frac{\sigma_\theta^{(1)0}}{\gamma H}$	$-\frac{\tau_{\rho\theta}^{(0)0}}{\gamma H}$	$-\frac{\tau_{\rho\theta}^{(1)0}}{\gamma H}$	$-\frac{\tau_{\theta\rho}^{(0)0}}{\gamma H}$	$-\frac{\tau_{\theta\rho}^{(1)0}}{\gamma H}$
0	0.250	0.000	1.000	0.000	0.000	0.000	0.000	0.000
15	0.300	0.188	0.949	-0.188	0.188	0.325	0.188	0.325
30	0.438	0.563	0.813	-0.563	0.325	0.325	0.325	0.325
45	0.625	0.750	0.625	-0.750	0.375	0.000	0.375	0.000
60	0.813	0.563	0.438	-0.563	0.325	-0.325	0.325	-0.325
75	0.949	0.188	0.302	-0.188	0.188	-0.325	0.188	-0.325
90	1.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000
105	0.949	0.188	0.302	-0.188	-0.188	0.325	-0.188	0.325
120	0.812	0.563	0.438	-0.563	-0.325	0.325	-0.325	0.325
135	0.625	0.750	0.625	-0.750	-0.375	0.000	-0.375	0.000
150	0.438	0.563	0.813	-0.563	-0.325	-0.325	-0.325	-0.325
165	0.300	0.188	0.949	-0.188	-0.188	-0.325	-0.188	-0.325
180	0.250	0.000	1.000	0.000	0.000	0.000	0.000	0.000

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Figure 2 shows the main radial stresses in the zero and first approximation of a solid massif, which are distributed symmetrically about the coordinate axes, and in this case the rock mass experiences only compression. The value of the radial stress at the upper points of the contour is 4 times greater than the stresses at the lateral points, and the circumferential stresses, on the contrary, are greater.

Figure 3 shows the main circumferential stresses in the zero and first approximation.

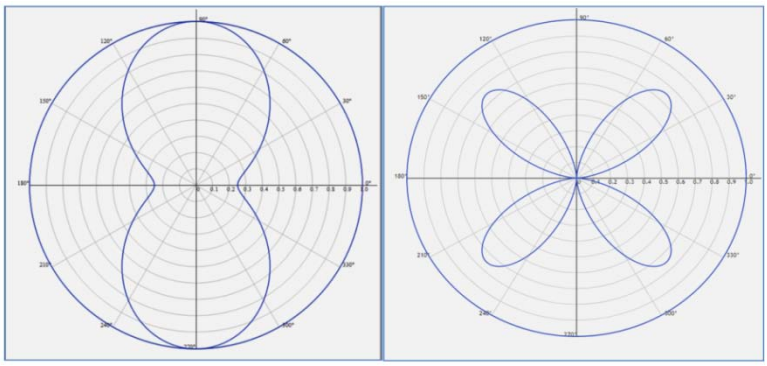

Fig. 2: Basic Radial Stresses in Zero and First Approximation

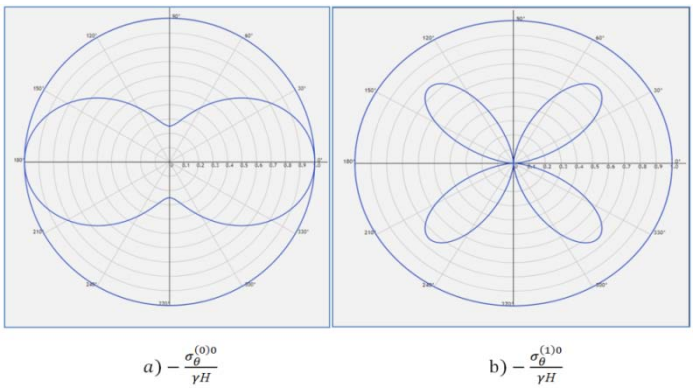

Fig. 3: Basic Circumferential Stresses in Zero and First Approximation

From Figure 3, we can conclude that the stresses are symmetrical with respect to the coordinate axes and the rock mass experiences only compression.

Figure 4 shows that the main shear stresses in the zero and first approximation are symmetrical about the axis of the bisector of the first quarter. In this case, in the first and third quarters, the array experiences only compression, and in the rest of the area, tension.

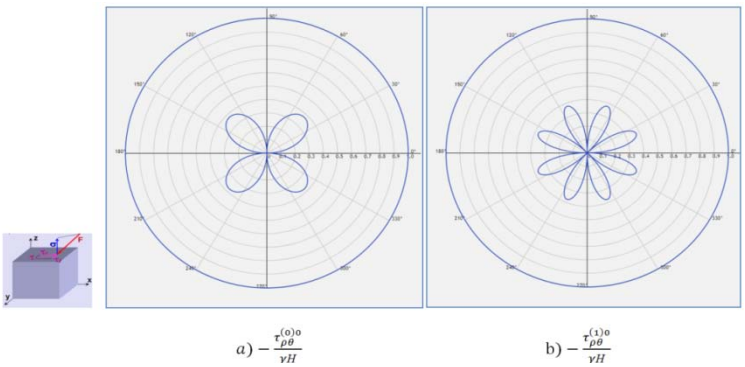

Fig. 4: Basic Shear Stresses in Zero and First Approximation

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Table 2 shows the values of additional stresses at the initial moment of time, calculated by formulas (22) and (24) in dimensionless units.

Figure 5 shows additional moment hoop stresses in zero and first approximation.

Table 2: Additional Stresses in the Rock Mass Around the Loose Elliptical Working

θ, degree	$-\frac{\sigma_\rho^{(0)00}}{\gamma H}$	$-\frac{\sigma_\rho^{(1)00}}{\gamma H}$	$-\frac{\sigma_\theta^{(0)00}}{\gamma H}$	$-\frac{\sigma_\theta^{(1)00}}{\gamma H}$	$-\frac{\tau_{\rho\theta}^{(0)00}}{\gamma H}$	$-\frac{\tau_{\rho\theta}^{(1)00}}{\gamma H}$	$-\frac{\tau_{\theta\rho}^{(0)00}}{\gamma H}$	$-\frac{\tau_{\theta\rho}^{(1)00}}{\gamma H}$	$\frac{\mu_\theta^{(0)00}}{\gamma HR}$	$\frac{\mu_\theta^{(1)00}}{\gamma HR}$
0	-0.250	0.000	1.359	2.624	0.000	0.000	0.000	0.000	-0,195	0,519
15	-0.302	-0.188	1.261	2.177	-0.1885	-0.325	0.261	-0.543	-0,169	0,329
30	-0.434	-0.563	0.992	1.099	-0.3258	-0.325	0.452	0.005	-0,098	0,462
45	-0.625	-0.750	0.625	-0.025	-0.375	0.000	0.522	1.495	0,000	0,216
60	-0.813	-0.563	0.258	-0.749	-0.325	0.325	0.452	2.585	0,098	0,152
75	-0.949	-0.188	-0.011	-1.027	-0.188	0.325	0.261	2.038	0,169	0,001
90	-1.000	0.000	-0.109	-1.074	0.000	0.000	0.000	0.000	0,195	-0,065
105	-0.949	-0.188	-0.011	-1.027	0.188	-0.325	-0.261	-2.038	0,169	0,057
120	-0.813	-0.563	0.258	-0.749	0.325	-0.325	-0.452	-2.585	0,098	0,045
135	-0.625	-0.750	0.625	-0.025	0.375	0.000	-0.522	-1.495	0,000	0,364
150	-0.437	-0.563	0.992	1.099	0.325	0.325	-0.452	-0.005	-0,098	0,287
165	-0.301	-0.188	1.261	2.177	0.188	0.325	-0.261	0.5437	-0,169	0,513
180	-0.250	0.000	1.359	2.624	0.000	0.000	0.000	0.000	-0,195	0,342

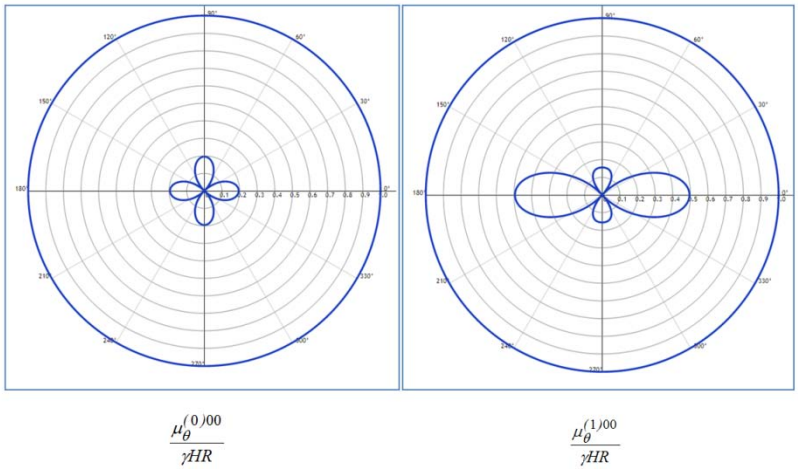

Fig. 5: Basic Additional Moment Stresses in Zero and First Approximation

Analysis of Figure 5 shows that the first distribution is symmetrical, while the second distribution is symmetrical about the X and Y axes and asymmetric about the axes of the first and third, as well as the second and fourth quarters.

Total stresses, displacements and rotations for an elliptical working are calculated as the sum of the zero and first approximations (main and additional).

V. Conclusion

Thus, the task of determining the potential stress functions that affect a certain system is completely solved. The advantage of the study is that the task is complicated by taking into account the moment stresses that cause deformations of curvature and rotation in the system. This increases the risk of loss of stability of the system and the rate of its destruction.

The use of such methods as mathematical and computer modeling, the use of numerical methods, contributed to obtaining adequate solutions to the problem.

The graphical implementation of the obtained numerical results makes it possible to see the critical zones in which the system experiences the greatest pressure from external forces. As a result, the system can lose its stability and go into a nonequilibrium state. It is in these areas that engineering construction requires urgent measures such as strengthening and strengthening mechanisms with effective technological solutions to avoid possible catastrophic collapses.

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The adoption of preventive measures to identify the risks of disasters by identifying critical areas and tools for their neutralization can be widely used in the analysis of the behavior of complex systems that are affected by some external forces.

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Group Pursuit on a Plane with Modeling Detection Area

By Alexander Dubanov
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Abstract- This article describes the pursuit model by the method of chasing a group of objects. All objects participating in the pursuit model move at a constant modulo velocity. The pursuing object moves along a certain trajectory and releases objects at specified intervals, whose task is to overtake the target by the chase method. A single target, in turn, is tasked to overtake the pursuer by the method of parallel convergence. A detection area is formed for each pursuing object. The detection area is formed by two beams. The velocity vector of an object is the bisector of the angle formed by such rays. If the target is in the detection area, then the object begins the pursuit by the chase method. If the target leaves the detection area, then the object makes a uniform and rectilinear movement.

The task is to implement a dynamic model of multiple group pursuing, where each object has its own tasks, its own strategies. The model is developed using computer mathematics systems. According to the results of the research, animated images were created. Targeting methods such as the chase method, the parallel approach method and the proportional approach method are widely used in military affairs. But they, for the most part, require external control, such as pointing the target with a laser beam or satellite guidance to the target. There is no description of methods of targeting in offline mode in open sources of information. The research results may be in demand when designing unmanned aerial vehicles with elements of autonomous control and artificial intelligence.

Keywords: *iparallel pursuit, chase method, target, pursuer, trajectory, correction.*

GJCST-H Classification: *DDC Code: 629.133134 LCC Code: TL770*

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Group Pursuit on a Plane with Modeling Detection Area

Alexander Dubanov

Abstract- This article describes the pursuit model by the method of chasing a group of objects. All objects participating in the pursuit model move at a constant modulo velocity. The pursuing object moves along a certain trajectory and releases objects at specified intervals, whose task is to overtake the target by the chase method. A single target, in turn, is tasked to overtake the pursuer by the method of parallel convergence. A detection area is formed for each pursuing object. The detection area is formed by two beams. The velocity vector of an object is the bisector of the angle formed by such rays. If the target is in the detection area, then the object begins the pursuit by the chase method. If the target leaves the detection area, then the object makes a uniform and rectilinear movement.

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Keywords: parallel pursuit, chase method, target, pursuer, trajectory, correction.

I. Introduction

Methods of chase and parallel approach, as well as proportional approach are widely used methods of aircraft guidance.

In this article, a model of group pursuit is proposed for consideration, when the pursuer moves along a certain trajectory. The target approaches the pursuer by the method of parallel approach. The pursuer releases objects at certain intervals that will pursue the target using the chase method. Objects start from their points on the pursuer's path.

This model is given in the article as an example. The target can approach the pursuer by both the chase method and the proportional method or some other method. The pursuer has little maneuverability, but releases objects that have the ability to homing. In the model of the article, homing objects are released perpendicular to the pursuer'strajectory.

This article describes the modeling of a group survey. Earlier, in the works of R. Isaacs [1], L. O. Petrosyan [2], N.N. Krasovsky [3], the methods of parallel approach and pursuit were described, the concept of a terminal set was introduced. The articles by A.S. Bannikov [4], M.V. Khachumov [5], [6] considered algorithmic aspects of group pursuing. In the works of T.G. Abramyants, E.P. Maslov, V.P. Yakhno [7], Gusyatnikov P.B. [8], [9], [10] the issues of evasion in three-dimensional space were considered. The article by Bogdanov A.V., Filonov A.A., Kovalev A.A., Kuchina A.A., Lyutikova I.V. [11] discussed methods of homing fighters and air-to-air missiles to a group air target. In the work of Nikitchenko S. N., Bassauer A. A. [12], the issues of mutual pursuit of air targets were considered. The article by Kuzmina L.I., OsipovaYu.V. [13] considered the calculation of the trajectory length in pursuit tasks.

In the model of the article, the pursuing objects descend perpendicular to the trajectory of the pursuer. The vanishing angle in the model is chosen as an example. The vanishing angle can be any Descending from the trajectory in the model, sequential and at regular intervals are selected.

Each pursuing object has a detection area formed. In the model, for example, the area is formed as an angle with a vertex at the point where the object is located. The bisector of this angle coincides with the direction of the object's velocity.

II. Problem Statement

Consider the movement of the pursuer along a certain trajectory on the plane:

$$\vec{P}(t) = \begin{bmatrix} X_P(t) \\ Y_P(t) \end{bmatrix}.$$

At time t_n, an object is separated from the pursuer's trajectory in a direction perpendicular to the pursuer's velocity vector:

$$\vec{N}(t_n) = \begin{bmatrix} -\frac{dY_p}{dt}(t = t_n) \\ \frac{dX_p}{dt}(t = t_n) \end{bmatrix}. \quad (1)$$

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Fig. 1 shows that in the model considered in the article, five objects are sent perpendicular from the pursuer trajectory, which after separation will move uniformly and rectilinearly with a speed equal to modulo V_G.

Fig. 1 is supplemented with an animated image [14], where it will be possible to see how from the pursuer's trajectory at certain intervals objects $G_n(t)$ are separated.

The simulation is performed on a section of the plane $[-60:130] \times [0:190]$. The measurement is made in meters. The pursuer moves at a constant speed $V_P = 20\ m/s$. Objects that break off perpendicular to its trajectory have a velocity $V_G = 40\ m/s$.

Figure 2 shows a network of parallel lines. As you can see, the initial positions of the pursuer and the target, the pursuer's initial speed determine the entire course of the iterative process. The pursuer's trajectory completely and unambiguously determines the trajectory of the target.

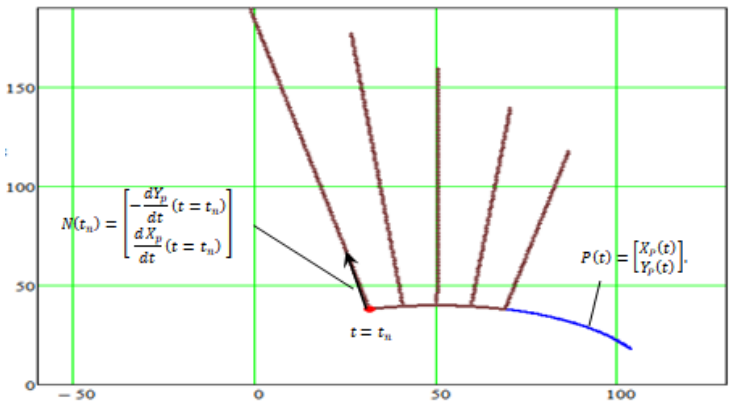

Figure 1: Simulation of the movement of objects descending perpendicular to the pursuer's trajectory

The target $\vec{T}(t)$ pursues $\vec{P}(t)$ by the method of parallel approach. Figure 2 is supplemented with an animated image [15], where it will be possible to see the movement on the plane of the target and the pursuer.

Let's simulate a situation when objects moving on a plane approach. One object pursues another by the method of parallel approach (Figure 2).

Figure 2 shows the trajectory of the target $\vec{T}(t)$ moving uniformly with a velocity modulus $V_T = 25\ m/s$.

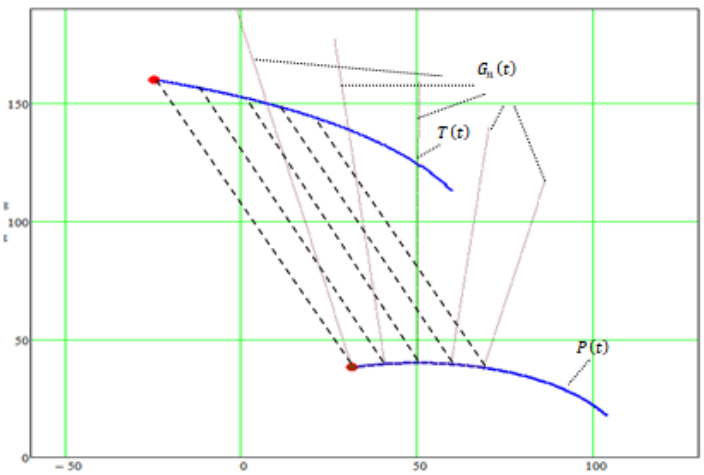

Figure 2: Modeling of the trajectory of the target moving towards the pursuer by the method of parallel approach

One of the objects, trying to defend itself, releases a group of homing objects.

The task that we have set in this article is to simulate the trajectories of objects $G_n(t)$ pursuing the goal $\vec{T}(t)$ using the chase method.

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III. Solution Methods

The method of parallel approach can be schematically depicted as shown in Figure 3a, when the target $T(t)$ approaches in parallel to the pursuer $P(t)$.

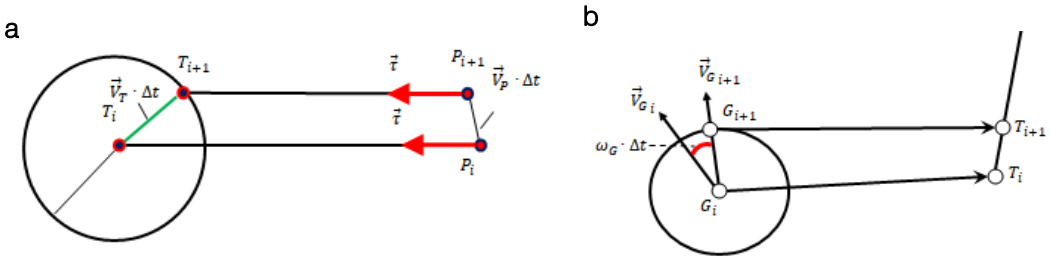

Figure 3: Methods of parallel approach and correction during the chase

Following the iterative scheme shown in Figure 3a, the step of the target trajectory $\vec{T}_{i+1}$ satisfies the solution of the system of equations (2), with respect to the parameter h:

$$\begin{cases} \left(\vec{T}_{i+1} - \vec{T}_i\right)^2 = \left(\left|\vec{V}_T\right| \cdot \Delta t\right)^2 \\ \vec{T}_{i+1} = \vec{P}_{i+1} + h \cdot \dfrac{\vec{T}_i - \vec{P}_i}{\left|\vec{T}_i - \vec{P}_i\right|} \end{cases}. \qquad (2)$$

The target's next step $\vec{T}_{i+1}$ belongs to a circle of radius $\left|\vec{V}_T\right| \cdot \Delta t$, centered at the point of the previous location $\vec{T}_i$, the first equation of the system (2). At the same time, the point of the next position $\vec{T}_{i+1}$ belongs to a straight line applied to the point $\vec{P}_{i+1}$ with a guide vector $\vec{T}_i - \vec{P}_i$. The second equation of the system (2) displays the parametric equation of this line.

In the chase method, the velocity vector of the object that is catching up is always directed at the object that is being overtaken.

In our case, this is not the case. Let the catching object be located at some time t_i at the point G_i, while having a velocity vector $\vec{V}_{G_i}$ (Fig. 3b). After a period of time Δt, the catching object rotates by an angle $\omega_G \times \Delta t$ and moves to a distance $V_G \cdot \Delta t$, where ω_G is the angular rotation frequency of the catching object.The angular rotation frequency can be interpreted as:

$$\omega_G = \frac{V_G}{R_G},$$

Where R_G is the minimum curvature radius of the trajectory of the catching object, that is, the curvature limit.

Consider the motion function of catching up objects $\vec{G}_n$ (Figure 1), when they move along the pursuer's trajectory $\vec{P}(t)$ before the moment of time t_n.

If at the moment of time t_n the direction changes to the direction $\vec{N}(t_n)$ specified in (1), then the coordinates of the object $\vec{G}_n$ are determined as follows:

$$\vec{G}_n(t) = \begin{cases} \text{если } t < t_n, \quad \text{то } \vec{G}_n(t) = \vec{P}(t) \\ \text{если } t \geq t_n, \quad \text{то } \vec{G}_n(t) = \vec{P}(t_n) + V_G \cdot (t - t_n) \cdot \dfrac{\vec{N}(t_n)}{\left|\vec{N}(t_n)\right|} \end{cases}$$

Based on the results of modeling the process of group pursuit of an object by the chase method, a program was written in a computer mathematics system, the results of which are shown in Figure 4.

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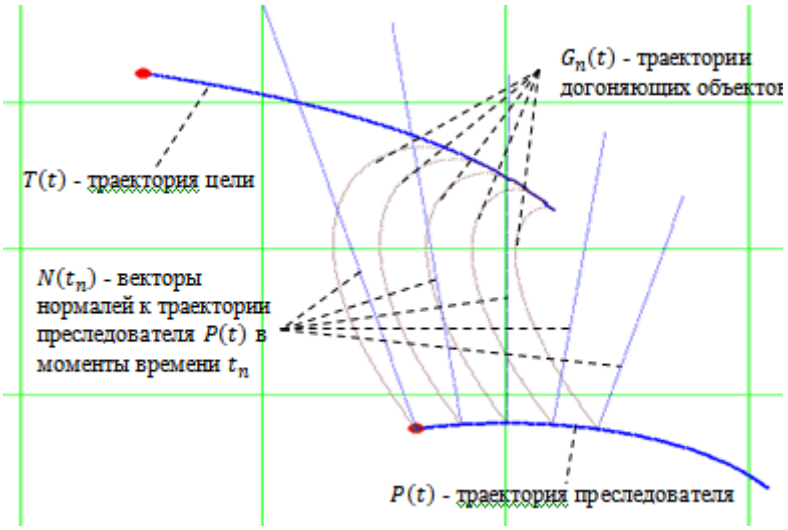

Figure 4: The process of chasing a target by a group of objects using the chase method

An animated image of the group pursuit of a single target by objects that descend perpendicular at certain intervals from the pursuer's trajectory was also produced [16].

The formation of the tracking area of objects $\vec{G}_n$ for the target $\vec{T}$ is performed as follows.

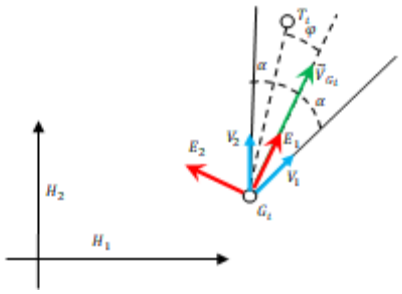

Figure 5: Forming the Tracking Area

A local coordinate system is being created $(\vec{E}_1 \quad \vec{G}_i \quad \vec{E}_2)$ (Figure 5), where $\vec{G}_i$ is the location of the pursuing object at the moment t_i. The abscissa vector $\vec{E}_1$ of the object is co-directed to the velocity vector $\vec{V}_{G_i}$. Accordingly, the ordinate vector $\vec{E}_2$ is orthogonal to the velocity vector $\vec{V}_{G_i}$.

The tracking area is given by an angle of magnitude 2α, the direction of the velocity vector $\vec{V}_{G_i}$ is the bisector of this angle. In the coordinate system $(\vec{E}_1 \quad \vec{G}_i \quad \vec{E}_2)$the vectors $\vec{V}_1$ and $\vec{V}_2$ defining the tracking area are determined:

$$\vec{V}_1 = \begin{bmatrix} cos(\propto) \\ -sin(\alpha) \end{bmatrix}, \vec{V}_2 = \begin{bmatrix} cos(\propto) \\ sin(\alpha) \end{bmatrix}.$$

The conversion of the coordinates of the target point $\vec{T}_i$ is carried out according to the formulas:

$$\vec{T}_i^* = \begin{bmatrix} (\vec{T}_i - \vec{G}_i) \cdot \vec{E}_1 \\ (\vec{T}_i - \vec{G}_i) \cdot \vec{E}_2 \end{bmatrix}.$$

If the angle φ between the vectors $\vec{T}_i - \vec{G}_i$ and $\vec{V}_{G_i}$ is less than α, then the target $\vec{T}$ at time t_i is in the tracking area of the pursuing object. The angle φ is equal to:

$$\varphi = \left| arcos\left(\frac{(\vec{T}_i - \vec{G}_i) \cdot \vec{V}_{G_i}}{|\vec{T}_i - \vec{G}_i| \cdot |\vec{V}_{G_i}|} \right) \right|.$$

a) The Behavior Model of the Pursuing Object

Modeling tracking angles of pursuing objects G_n in the world coordinate system $(H_1 \quad H_2)$is essentially aconversion vectors $\vec{V}_1$ and $\vec{V}_2$ from the coordinate system $(\vec{E}_1 \quad \vec{G}_i \quad \vec{E}_2)$ to the world.

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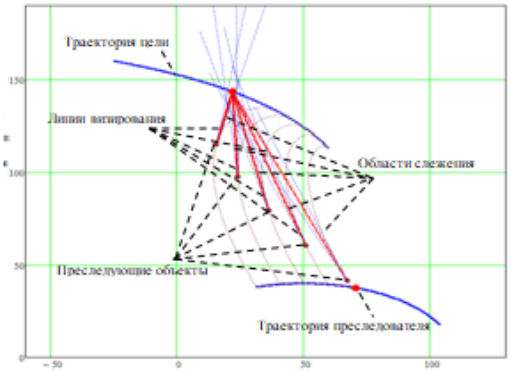

Figure 6: Dynamic Tracking Areas of Pursuing Objects

Converting vectors $\vec{V}_1$ and $\vec{V}_2$ from the coordinate system $(\vec{E}_1 \quad \vec{G}_i \quad \vec{E}_2)$ to the world $(\vec{H}_1 \quad \vec{H}_2)$ it looks like this:

$$\vec{v}_1 = \begin{bmatrix} \vec{V}_1 \cdot \vec{h}_1 \\ \vec{V}_1 \cdot \vec{h}_2 \end{bmatrix} + \vec{G}_i, \vec{v}_2 = \begin{bmatrix} \vec{V}_2 \cdot \vec{h}_1 \\ \vec{V}_2 \cdot \vec{h}_2 \end{bmatrix} + \vec{G}_i . \vec{h}_1 = \begin{bmatrix} \vec{H}_1 \cdot \vec{E}_1 \\ \vec{H}_1 \cdot \vec{E}_2 \end{bmatrix}, \vec{h}_2 = \begin{bmatrix} \vec{H}_2 \cdot \vec{E}_1 \\ \vec{H}_2 \cdot \vec{E}_2 \end{bmatrix}, \vec{H}_1 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}, \vec{H}_2 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}.$$

Figure 6 shows how the tracking areas of the pursuing objects are formed, Figure 6 is supplemented with an animated image [17]. In Figure 5, the pursuing objects catch up with the target by the chase method without changing behavior, depending on whether the target enters the tracking area. Tracking areas are displayed for each object. The lines of sight connecting the pursuing object with the target are also displayed. Consider the behavior of the pursuing object.

Figure 7: The Target is Out of the Detection Zone

Figure 7 shows that if at some point in time the target does not enter the detection area, then the pursuing object moves in a straight line. If the target has entered the detection area, then the behavior of the pursuing object corresponds to the chase method. Figure 7 is supplemented with an animated image [18].

IV. Results

In modeling the process of group pursuit, the method of chasing objects starting perpendicular to the pursuer'strajectory is used. In the model described in the article, nothing prevents us from replacing the chase method with the parallel approach method for catching up objects. Andnothing prevents us from replacing the descent perpendicular to the pursuer's trajectory is replaced by a tangent descent.

Based on the results of the research presented in this article, modeling was performed in a rectangular area $[-60:130] \times [0:190]$, measurement in meters.

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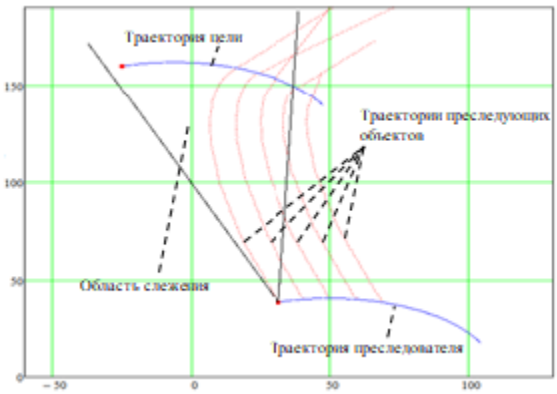

Figure 8: Group Pursuing Model

Figure 8 shows the simulation results. The pursuer's speed is $20\ m/s$, the target's speed is $20\ m/s$.The speed of the pursuing objects is 60 m / s. The curvature radius of the pursuer's trajectory should not be less than 50 m. The target pursues by parallel approach, the curvature radius of the trajectories of the pursuing objects should not be less than $10\ m$. The pursuing objects descend perpendicularly from the pursuer's trajectory at regular intervals of $0.02\ s$. Figure 8 is supplemented with an animated image [19], where it will be possible to get acquainted with the results of such a group pursuit.

In the simulation presented in this article, all objects released from the trajectory reach the target. This result depends on several factors: on the angle of the detection zone, on the speed of the pursuing objects, on the value of the minimum curvature radius of the object trajectories.

In the model considered in the article, it is found out that in order to avoid being hit by a pursuing object, it is necessary to leave the detection area. The closer the pursuing object is, the fewer iteration steps the target needs to take in order to leave the detection area.

For the pursuing object, the guaranteed result of catching the target would be to switch to the movement direction, the vector of which would be co-directed to the vector of the target's speed. Based on the results of the program, a certificate of state registration of the computer program No. 2020614336 "Modeling of trajectories from the pursuer to the target with curvature restrictions and with specified boundary conditions" was issued [20].

V. Conclusions

The results obtained in this article could be used in the development of unmanned aerial vehicles with autonomous control, equipped with elements of artificial intelligence. It is also possible to use the results with satellite guidance of barrage projectiles.

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Comments on "Friis Transmission over a Ground Plane"

By Valentino Trainotti

Abstract- The Friis Equation [1] had been used to calculate the power budget between antenna gains and space losses in any radio link with no obstructions in the path between the antenna elements, [10]. It can be used to obtain perfect answers when applied to links in free space and over perfect ground without any modifications or additions [7],[8].

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Comments on "Friis Transmission over a Ground Plane"

Valentino Trainotti

Abstract- The Friis Equation [1] had been used to calculate the power budget between antenna gains and space losses in any radio link with no obstructions in the path between the antenna elements, [10]. It can be used to obtain perfect answers when applied to links in free space and over perfect ground without any modifications or additions [7],[8].

PROOF:

I. Radio Link in Free Space with Two Half-Wave Dipole Antennas

In free space radio link between two identical resonant and perfectly matched half-wave dipole antennas the theoretical results, taking into account that the power gain is exactly equal to the directivity, are the following:

Tx antenna theoretical power gain G_T= 2.15 (dBi)
Tx antenna theoretical effective area A_{eT}= 0.13 λ^2.
Tx antenna theoretical effective length L_{eT}= 0.3183 λ.
Rx antenna theoretical receiving power gain G_R= 2.15 (dBi).
Rx antenna theoretical receiving effective area A_{eR}= 0.13 λ^2.
Rx antenna theoretical scattering power gain G_s= -0.85 (dBi).
Rx antenna theoretical scattering effective area A_{es}= 0.065λ^2.
Rx antenna theoretical effective length L_{eR}= 0.3183 λ.

Tx antenna power gain G_T in free space [2],[3]:

$$G_T = 2.15 \text{ (dBi)}$$

Rx antenna effective receiving area A_{eR} definition [2],[3]:

$$A_{eR} = W_R/P_i$$

In a simulation made up by means of a software program (WIPL-D) [6] and additional calculations for parameters not obtained by the software, the results are the following:

For f = 300 (MHz), λ = 1 (m), r = 100 (m),

R_{aT} = R_{aR} = 71.0 (Ω), R_L = 71 (Ω), W_T = 1 (W).

Tx antenna power gain G_T = 2.12 (dBi).
Tx antenna effective area A_{eT} = 0.13 (m^2).
Tx antenna effective length L_{eT} = 0.3183 (m).
Tx Antenna factor aF_{T73} = 15.97 (dB/m).
Tx Antenna factor aF_{T50} = 17.61 (dB/m).
Rx antenna receiving power gain G_R = 2.15 (dBi).
Rx antenna receiving effective area A_{eR} = 0.13 (m^2).
Rx antenna scattering power gain G_s = -0.89 (dBi).
Rx antenna scattering effective area A_{es} = 0.065 (m^2).
Rx antenna effective length L_{eR} = 0.3183 λ.
Rx antenna received current I_R = 1.5 E-4 (A).
Rx antenna received voltage V_R = 1.09 E-2 (V).
Rx antenna received power W_R = 1.68 E-6 (W).
Rx Antenna factor aF_{R73} = 15.97 (dB/m).
Rx Antenna factor aF_{R50} = 17.61 (dB/m).

In this example, the Friis power budget is shown because for a perfect resonant and matched antenna the theoretical power gain or directivity are exactly the same [3]. In this case, the difference between directivity and gain is negligible or around 0.01 dB. Antenna efficiency is around 97 percent. Generally, losses are in the matching systems or in transmission lines but not in the antennas and must be computed separately. The transmission loss or site attenuation for a distance r = 100 (m) and for the transmitted power W_T = 1 (W), is:

$$A_w = 10logW_R = 10log1.68E-6 = -57.75(dB)$$

The nondissipative free space attenuation, is:

$$A_{FS} = 10log(\lambda/4\pi r)^2 = -61.98(dB)$$

Using the secondary or additional Friis equation [3] for the parameters in dB, results in:

$$G_T + G_R = A_w - A_{FS} = K(dB).$$

$$G_T + G_R = 2.12 + 2.11 = 4.23(dB).$$

$$K = A_w - A_{FS} = -57.75 - (-61.98) = 4.23(dB)$$

Friis power budget was corroborated because the antenna gains are exactly the space losses.
Also, the power reciprocity principle from Schelkunoff and Friis [3] is confirmed, or:

$$A_{eT}/g_T = 0.079$$

$$A_{eR}/g_R = 0.079$$

$$A_{es}/g_s = 0.079$$

All data were the result of calculations and not assigning any supposed value at the antenna gains as well as it can be obtained by power measurements [7], [8]. In a radio link in

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free space the Tx and Rx antennas have the area, gain and factor of the same value [2],[3]. It is important to verify in any radio link if the reciprocity principle is fulfilled, to be:

$$A_{eT}/g_T = A_{eR}/g_R = A_{es}/g_s$$

II. Rx Half-Wave Dipole Antenna in Free Space and Short Circuit

Calculated by a software program (WIPL-D) [6] with the following data, for:

f = 300 (MHz), λ = 1 (m), r = 100 (m),

R_{aT} = R_{eR} = 71.0 (Ω), R_L = 0.0 (Ω), W_T = 1 (W).

Tx antenna power gain G_T = 2.13 (dBi).
Tx antenna effective area A_{eT} = 0.13 (m^2).
Tx antenna effective length L_{eT} = 0.3183 (m).
Rx antenna receiving effective area A_{eR} = 0.0 (m^2).
Rx antenna scattering power gain G_s = 2.13 (dBi).
Rx antenna scattering effective area A_{es} = 0.13 (m^2).
Rx antenna effective length L_{eR} = 0.3183 m.
Rx antenna received current I_R = 3.1 E-4 (A).
Rx antenna received voltage V_R = 0.0 (V).
Rx antenna received power W_R = 0.0 (W).
Rx antenna scattered power W_s = 6.91 E-6 (W).

In his original book "ANTENNAS" Dr. John Kraus [2] took as scattering area A_{es} the relation between the reradiated or scattered power W_s and the incoming power density P_i instead of calculating the scattering area A_{es}, that was suggested by Harald Friis [3], for the case of a transmitting or retransmitting antennas, according to the radiated numerical gain g_T or scattered numerical gain g_s. This event was repeated incorrectly in several other antenna theory books. Using the scattered area by Dr. Kraus the scattered gain G_s would acquire more than 8 (dBi) which is not possible for a simple half-wave dipole antenna in short circuit and free space. It can show calculations, that the maximum gain in short circuit, is exactly G_s = 2.15 (dBi) like the Tx antenna [10]. In reality both antennas are doing practically the same task, the Tx fed by the theoretical generator with zero internal impedance and the Rx fed by the incoming wave. This can be verified simply by means of the current distribution of both antennas fed by the same voltage $V_T = V_i$ where $V_i = E_i * L_{eR}$. E_i is the electrical field intensity of the incoming wave and L_{eR} is the antenna effective length. Figure 1 shows the same results as the Figure 3.3 in page 47 of Dr. Kraus antenna book [2], where the maximum effective scattering and receiving areas have the same value. Possibly in the fifties the most important task of a radio link was the radio communication for telegraphic or telephonic applications. Presently, electronic warfare and radar requires the knowledge of EM scattering of the Rx antennas in free space or installed over ground. The truth is in favor of Schelkunoff and Friis [3], because in their book the main Friis equation utilizing the main antenna parameters,

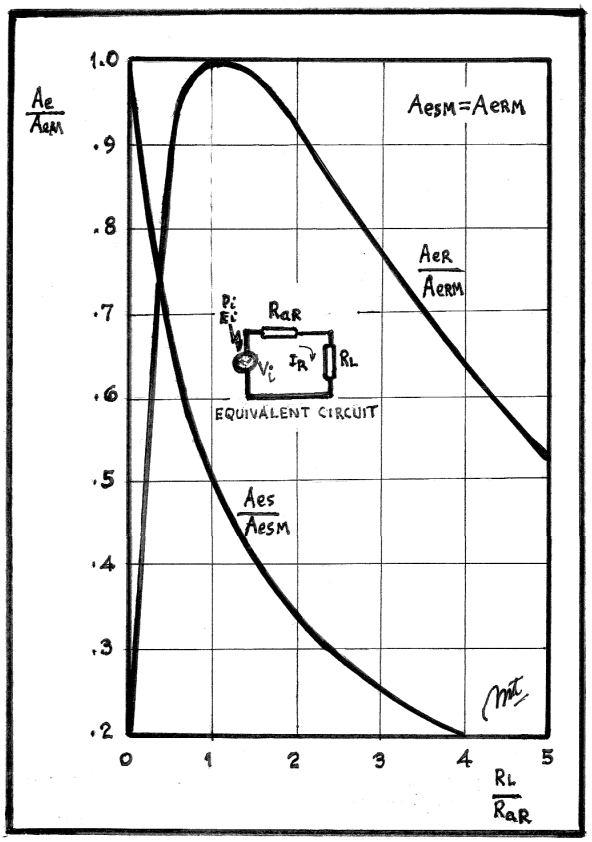

Figure 1. Variation of effective receiving area A_{eR} and effective scattering area A_{es} as a function of the relative terminal resistance R_L/R_{aR}, it is assumed identical theoretical antenna perfect resonant and matched.

gain for Tx antennas and area for Rx antennas, as well the secondary equation for areas and gain are clearly explained. At a radio link in free space or over ground minimum far field distance is achieved at the maximum Tx antenna radiation. Effective length L_{eR} and factor AF_R are inherent in the Rx antenna and independent of distance r and height H_R. Area and gain are far field parameters or when the wave impedance $Z_w = Z_{oo} = 120\,\pi \simeq 377\,(\Omega)$.

III. Radio Link between Two Identical Half-Wave Dipole Antennas Over Perfect Ground with Horizontal Polarization

Calculated by a software program (WIPL-D) [6] with the following data, for:

f = 300 (MHz), λ = 1 (m), r = 100 (m), H = 0.236 (m),
a = 2.5 (mm), $Z_{aT} = R_{aT}$ = 71.48 (Ω), H_T = 2 (m),
R_L = 71.5 (Ω), H_R = 12.6 (m)

Tx antenna power gain G_T over perfect ground [2],[3]:
G_T = 2.15 (dBi)(free space) + 3 (dB)(image effect) + 3 (dB)(half sphere space radiation) = 8.15 (dBi) (6 dB gain of the same antenna in free space)
Rx antenna effective receiving area A_{eR} definition [2],[3]:

$$A_{eR} = W_R/P_i$$

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The results obtained are:

Tx antenna power gain G_{TM} = 8.17 (dBi).
Tx antenna maximum power elevation angle α_{pM} = 7.2 °.
Tx antenna effective area A_{eTM} = 0.52 (m^2).
Tx antenna factor AF_{T71} = 10.0 (dB/m).
Tx antenna factor AF_{T50} = 11.5 (dB/m).
Rx antenna power gain G_R = 2.17 (dBi).
Rx antenna receiving effective area A_{eR} = 0.13 (m^2).
Rx antenna scattering power gain G_{sM} = 5.20 (dBi).
Rx antenna maximum scattering elevation angle α_{sM}=1.1°.
Rx antenna scattering effective area A_{esM} = 0.26 (m^2).
Rx antenna receiving current I_R = 3.1 E-4 (A).
Rx antenna receiving voltage V_R = 2.20 E-2 (V).
Rx antenna receiving power W_R = 6.74 E -6 (W).
Rx antenna factor AF_{R71} = 16.0 (dB/m).
Rx antenna factor AF_{R50} = 17.5 (dB/m).
Rx antenna resistance R_{aR} = 71 (Ω).
Rx antenna load R_L = 71 (Ω).
r' = $(r^2 + H_R^2)^{1/2}$ = 100.79 (m).
Maximum incoming power density P_{iM} = 5.139 E-5 (W/m^2).
Receiving power W_R = 6.74 E-6 (W).
Transmission loss or site attenuation:
A_w = -51.71 (dB).
Free space non dissipative attenuation:
A_{FS} = -62.05 (dB).
Friis secondary equation for parameters in dB:
$G_T + G_R$ = 8.17 + 2.17 = 10.34 (dB).
$A_w - A_{FS}$ = -51.71 - (-62.05) = 10.34 (dB).
Friis power budget fulfilled.
Schelkunoff and Friis power reciprocity principle:

A_{eT}/g_T = 0.079

A_{eR}/g_R = 0.079

A_{es}/g_s = 0.079

Power reciprocity principle fulfilled.
Incident power density or Poynting vector:

$$P_{iM} = (RP_y^2 + RP_z^2)^{1/2} = 5.139E-5 (W/m^2).$$

Power density elevation angle of the Tx radiation pattern first lobe:

$$\alpha_{pM} = tg^{-1}(RP_z/RP_y) = 7.2\ °.$$

Of course, exactly the same elevation angle of the Tx antenna radiation pattern. The maximum power density P_{iM} is travelling along the line of distance r' between antennas shown in Figure 2 and at the lower lobe shown in figure 3, fulfilling the Fermat principle.
Maximum scattering power density P_{sM} has an elevation angle for the first lobe of α_{sM} = 1.1 ° due to the Rx antenna scattering radiation pattern at the height H_R. The Rx antenna is a more complex system than the Tx antenna because it

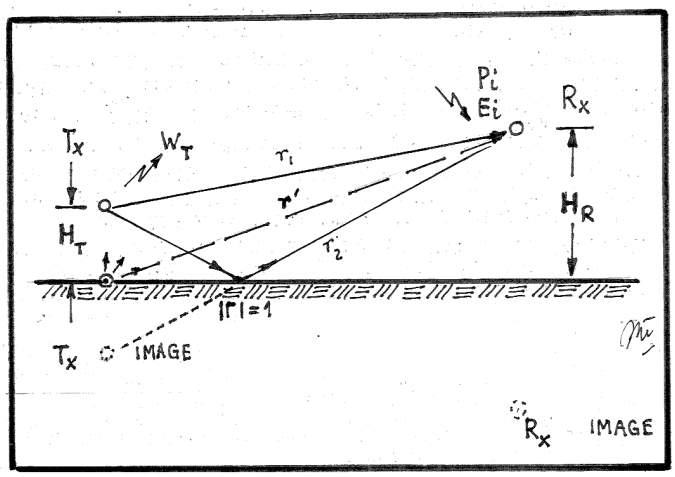

Figure 2. Radio link between two identical half-wave dipole antenna over perfect ground and horizontal polarization. r' distance connects the Tx antenna geometrical center or center phase with the Rx antenna center. Power density P_i travels along this line.

needs to deliver power to the load R_L and, at the same time, scatters EM energy to the surrounding space. These two task have a different radiation patterns, as suggested by Schelkunoff and Friis [3] in his antenna book, but this property was not expanded in their treatise. Rx antenna pattern is practically omnidirectional because it delivers the EM energy on its resistive load but nothing on its image, so it is performing like in free space.
This is confirmed by its gain of around 2 (dBi) and almost constant if the Rx antenna is scanned in its height H_R [**?**]. In this case the G_R is always close to 2 (dBi) from H_R till very close to ground and decreasing slowly to $-\infty(dBi)$ at zero height. The Rx antenna scattering pattern depends, like a Tx antenna, on its height over ground as shown in Figure 3. In this case the Rx antenna height is 12.6 λ and it produces 25 lobes between zero and 90 degrees. The Tx antenna at 2 λ height produces 4 lobes as shown in Figure 3. It is useful to see the area, gain and factor relation between the Tx and Rx antennas working over perfect ground:

$$A_{eT}/A_{eR} = 0.52/0.13 = 4.0\ \ (6\,dB).$$

$$g_T/g_R = 6.56/1.65 = 3.98\ \ (6\,dB).$$

$$AF_{T50}/AF_{R50} = 3.80/7.58 = 0.5\ \ (-6\,dB).$$

For identical resonant and perfectly matched antennas over perfect ground the difference between Tx and Rx antennas of area, gain and factor is 6 dB [10].

IV. Rx Antenna in Short Circuit over Perfect Ground

Following values are considered:

f = 300 (MHz), λ = 1 (m), r = 100 (m), H = 0.236 (m),

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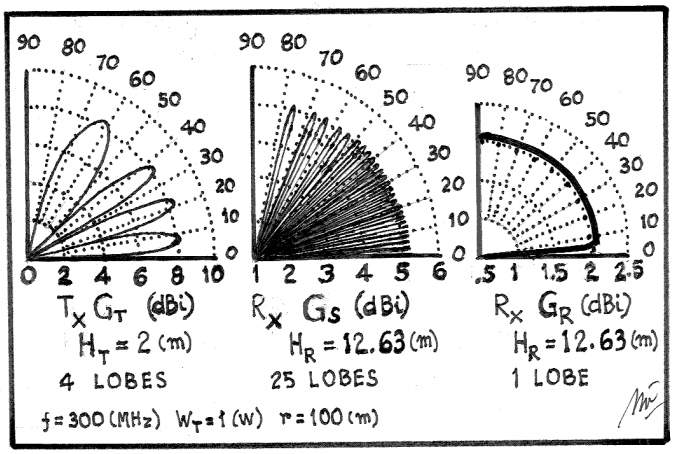

Figure 3. Radio link between two identical half-wave dipole antennas over perfect ground, Tx antenna radiation pattern and Rx antenna receiving and scattering radiation patterns. Tx and Rx antennas are resonant and perfectly matched.

a = 2.5 (mm), $Z_{aT} = R_{aT}$ = 71.48 (Ω), H_T = 2 (m),

a = 2.5 (mm), $Z_{aR} = R_{aR}$ = 71.00 (Ω), H_R = 12.6 (m),
R_L = 0.0 (Ω).

Yielding these results by sofware program (WIPL-D) [6], or:

Tx antenna power gain G_{TM} = 8.18 (dBi).
Tx antenna maximum power elevation angle α_{pM} = 7.2 °.
Tx antenna effective area A_{eTM} = 0.52 (m^2).
Rx antenna receiving effective area A_{eR} = 0.0 (m^2).
Rx antenna scattering power gain G_{sM} = 8.19 (dBi).
Rx antenna maximum scattering elevation angle α_{sM}= 1.1 °.
Rx antenna scattering effective area A_{esM} = 0.52 (m^2).
Rx antenna receiving current I_R = 6.2 E-4 (A).
Rx antenna scattering voltage V_s = 4.40 E-2 (V).
Rx antenna scattering power W_s = 2.73 E-5 (W).

In this case, Tx and Rx antenna have practically the same maximum power gain but different amount of lobes depending on their height over ground. Also, the effective scattering area calculated by the scattering numerical gain g_s or by the relation between the scattered power W_s and the incoming power density P_i yields practically the same result [10].

V. Radio Link between Two Identical Quarter-Wave Monopole Antennas over Perfect Ground

Tx antenna theoretical power gain G_T= 5.15 (dBi)
Tx antenna theoretical effective area A_{eT}= 0.26 λ^2.
Tx antenna theoretical effective height H_{eT}= 0.318 λ.
Rx antenna theoretical receiving power gain G_R= -0.85 (dBi).
Rx antenna theoretical receiving effective area

$$A_{eR} = 0.065\ \lambda^2.$$

Rx antenna theoretical scattering power gain G_s= 2.15 (dBi).
Rx antenna theoretical scattering effective area A_{es}= 0.13λ^2.
Rx antenna theoretical effective height H_{eR}= 0.159 λ.

Tx antenna power gain G_T over perfect ground [2],[3],[5]: G_T = -0.85(dBi)($\lambda/4$ monopole)+ 3 (dB)(image effect)+ 3 (dB)(half sphere space radiation) = 5.15 (dBi) (6 dB gain over $\lambda/4$ monopole, 3 dB gain over $\lambda/2$ dipole in free space)[10].
Rx antenna effective receiving area A_{eR} definition [2],[3]:
$A_{eR} = W_R/P_i$

Software program simulation (WIPL-D) [6], results in:
For f = 300 (MHz), λ = 1 (m), r = 100 (m),
H = 0.233 (m), a = 2.5 (mm),
$R_{aT} = R_{aR}$ = 35.06 (Ω), R_L = 50 (Ω), W_T = 1 (W).

Tx antenna power gain G_T = 5.12 (dBi).
Tx antenna effective area A_{eT} = 0.26 (m^2).
Tx antenna effective height H_{eT} = 0.318 (m).
Tx antenna factor AF_{T50} = 14.65 (dB/m).
Rx antenna receiving power gain G_R = -0.81 (dBi).
Rx antenna receiving effective area A_{eR} = 0.066 (m^2).
Rx antenna scattering power gain G_s = 2.11 (dBi).
Rx antenna scattering effective area A_{es} = 0.13 (m^2).
Rx antenna effective height H_{eR} = 0.159 (m).
Rx antenna factor AF_{R50} = 20.57 (dB/m).
Rx antenna received power density
$P_i = RP_y$ = 2.595 E-5 (W/m^2).
Rx antenna received power W_R = 1.68 E-6 (W).
Transmission loss or site attenaution A_w = -57.67 (dB).
Free space non dissipative attenuation A_{FS} = -61.98 (dB).
Secondary Friis equation in dB, results in:

$$G_T + G_R = 5.12 + (-0.81) = 4.31 \text{ (dB)}$$
$$A_w - A_{FS} = -57.67 - (-61.98) = 4.31 \text{ (dB)}$$

Friis power budget fulfilled.

Schelkunoff and Friis power reciprocity principle [3]:

$$A_{eT}/g_T = 7.96E-2$$

$$A_{eR}/g_R = 7.96E-2$$

$$A_{es}/g_s = 7.96E-2$$

Power reciprocity principle fulfilled.
Monopole antennas, factor, area and gain relations are obtained, as:

$$aF_{T50}/aF_{R50} = 5.40/10.68 = 0.51\ \ (-5.92dB).$$

$$A_{eT}/A_{eR} = 0.26/0.066 = 3.94\ \ (5.95dB).$$

$$g_T/g_R = 3.25/0.83 = 3.92\ \ (5.93dB).$$

Relations are very close to 6 dB [10].
The power received $W_R = 1.68E-6(W)$ by this radio link is exactly the same as the radio link between two identical half-wave dipole antennas in free space shown previously. This fulfills the Kenneth Alva Norton Statement [4], or:

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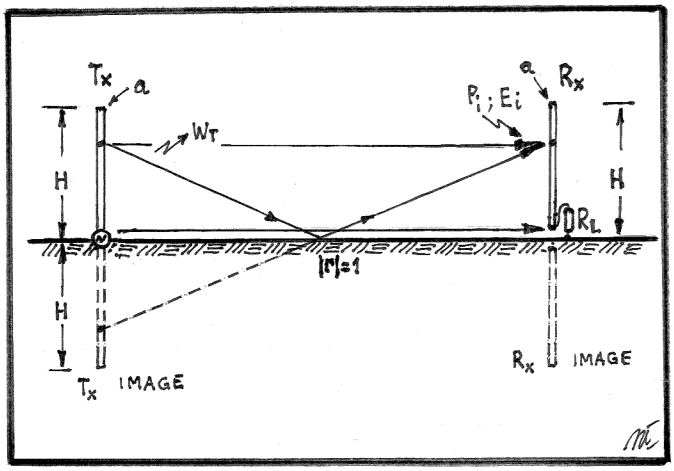

Figure 4. Radio link between two quarter-wave identical monopole antennas over perfect ground. The reflexion effect can be seen as the radiation of the Tx antenna image. Rx antenna image doesn't receive any Tx radiation, because the surface is not transparent.

"A radio link between two half-wave dipole antennas in free space delivers the same power W_R in the receiving load as a radio link between two quarter wave monopole antennas over perfect ground if the power W_T and distance r is the same value".

Calculations performed here show that the Norton Statement [4] is perfectly fulfilled if the real or natural antenna gains are used and, therefore, no artificial factors are needed to be introduced to fulfill this Statement, as well as the Friis power budget and the power reciprocity principle [7], [8].
Here no antenna gain were changed in any case like in the papers commented, [7], [8], to force the power budget fulfillment.

VI. Rx Quarter-Wave Monopole Antenna in Short Circuit

Tx antenna theoretical power gain G_T= 5.15 (dBi)
Tx antenna theoretical effective area A_{eT}= 0.26 λ^2.
Tx antenna theoretical effective height H_{eT}= 0.318 λ.
Rx antenna theoretical receiving effective area A_{eR}= 0.0 λ^2.
Rx antenna theoretical scattering power gain G_s= 5.15 (dBi).
Rx antenna theoretical scattering effective area A_{es}= 0.26λ^2.
Rx antenna theoretical effective height H_{eR}= 0.318 λ.

Results using software program (WIPL-D) [6]:

Tx antenna power gain G_T= 5.12 (dBi)
Tx antenna effective area A_{eT}= 0.26 m^2.
Tx antenna effective height H_{eT}= 0.318 (m).
Rx antenna receiving effective area A_{eR}= 0.0 m^2.
Rx antenna scattering power gain G_s= 5.12 (dBi).
Rx antenna scattering effective area A_{es}= 0.26 m^2.
Rx antenna effective height H_{eR}= 0.318 (m).

VII. Radio Link between Two Short Monopoles

National Institute of Standards and Technology (NIST) presents in the Technical Note 1347 (January 1991) [12] the calibration of short monopole antennas. These antennas are calibrated to be used as electromagnetic wide band sensors to determine the electromagnetic wave field strength. The procedure is partially theoretical and partially practical. It uses the theoretical equations to find the incoming electric field strength E_i over the receiving antenna [11] and the capacity of the receiving antenna C_{aR} [3]. Practically, it measures the input voltage V_{aT} of the transmitting antenna and the input voltage V_L of the calibrated receiving field strength meter. These equations are well known and published by books of Jordan [11] and Schelkunoff and Friis [3]. Both monopole antennas are non resonants or adapted at frequencies below $f = 10\,(MHz)$ because they are of a maximum height of 2.5 (m) for H_T and H_R. Here the simulation of a radio link with two short monopole antennas is calculated and the results are compared to the NIST results. NIST antenna range has a length of 60 (m) and a width of 30 (m) and the surface was metallized in order to get a perfect conductivity of $\sigma \geq 10^7\,(S/m)$, that can be considered as practically theoretical (reflexion factor $\Gamma \simeq 1$). The transmitting monopole antenna has a radius $a_1 = 2.5\,(mm)$ in its base and a radius $a_2 = 1.3\,(mm)$ at the top. The receiving monopole antenna has a radius as constant as $a = 0.81\,(mm)$. Measuring equipments and connexions are installed under ground avoiding interfiering the wave fields. NIST is using the classical receiving antenna factor aF_{aR}, to be:

$$aF_{R50} = \frac{E_i}{V_{R50}}\ (1/m) \tag{1}$$

Where:
E_i (V/m) is the incoming electric field on the receiving monopole antenna.
V_{R50} (V) is the measured input voltage on the calibrated receiver with $R_L = 50(\Omega)$ impedance.

In decibels, results in:

$$AF_{R50} = 20\,log\left(\frac{E_i}{V_{R50}}\right)\ (dB/m) \tag{2}$$

For a short monopole antenna $H_R \leq 0.1\,\lambda$ its effective height H_{eR} when the wave impedance is $Z_w = Z_{00} = 120\,\pi \simeq 377\,(\Omega)$, results in:

$$H_{eR} = \frac{V_i}{E_i} = \frac{H_R}{2}\ (m) \tag{3}$$

Where:
V_i (V) is the induced voltage by the incoming wave in the Thevenin receiving antenna equivalent circuit.
E_i (V/m) is the incoming electric field on the receiving monopole antenna.

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Thus:

$$E_i = \frac{V_i}{H_{eR}} \ (V/m) \tag{4}$$

From this relation NIST determines the receiving antenna factor aF_{R50} in the 50 Ω calibrated receiver, or:

$$aF_{R50} = \frac{E_i}{V_{R50}} = \frac{V_i}{V_{R50}\, H_{eR}} = \frac{I_R\,(R_{L50} + Z_{aR})}{I_R\, R_{L50}\, H_{eR}} \ (1/m) \tag{5}$$

I_R y R_{L50} are common factors in numerador and denominador, results in:

$$aF_{R50} = \frac{1 + \left(\frac{Z_{aR}}{R_{L50}}\right)}{H_{eR}} \ (1/m) \tag{6}$$

$Z_{aR} = R_{aR} + j\, X_{aR}$ is input impedance of the receiving antenna where the imaginary part X_{aR} is greater than the real part R_{aR}, or:

$$Z_{aR} \simeq -j\, X_{aR} \ (\Omega) \tag{7}$$

With $R_{L50} = 50\,(\Omega)$ the NIST receiving antenna factor equation, is:

$$aF_{R50} = \frac{X_{aR}}{50\, H_{eR}} = \frac{X_{aR}}{25\, H_R} \ (1/m) \tag{8}$$

In decibels, results in:

$$AF_{R50} = 20\, log\left(\frac{X_{aR}}{25\, H_R}\right) \ (dB/m) \tag{9}$$

NIST doesn't determine the receiving antenna input impedance but the receiving antenna capacity using the well known antenna capacity by the equation published by Schelkunoff and Friis [3], or:

$$C_{aR} = \frac{2\,\pi\,\epsilon_0\, H}{ln(H/a) - 1} \ (F) \tag{10}$$

From this equation the capacitive reactance X_{aR} is obtained:

$$X_{aR} = \frac{1}{2\,\pi\, f\, C_{aR}} \ (\Omega) \tag{11}$$

Using this procedure, where R_{aR} is negligible, the receiving antenna factor aF_{R50} is reactive and practically imaginary. Here, the simulation is performed as an example at the frequency $f = 3\,(MHz)$ by means for a radio link between two monopole antennas with the same physical geometry like NIST. The input impedance of both monopoles is obtained by a WIPL-D software [6], or:

$$Z_{aT} = (R_{aT} + jX_{aT}) = (0.24 - j2217) \ (\Omega) \tag{12}$$

$$Z_{aR} = (R_{aR} + jX_{aR}) = (0.24 - j2637) \ (\Omega) \tag{13}$$

Transmitted power W_T depends from the radiation resistance R_{aT} and the squared current I_T^2 of the transmitting antenna and for a transmitted power $W_T = 0.1\,(W)$, results in:

$$I_T = \left(\frac{W_T}{R_{aT}}\right)^{1/2} = \left(\frac{0.1}{0.24}\right)^{1/2} = 0.6455 \ (A) \tag{14}$$

The voltage V_T on the radiation resistance R_{aT}, results in:

$$V_T = (I_T\, R_{aT}) = 0.6455 \cdot 0.24 = 0.155 \ (V) \tag{15}$$

The voltage $V_{Z_{aT}}$ on the transmitting antenna impedance Z_{aT}, results in:

$$V_{Z_{aT}} = (I_T\, Z_{aT}) \ (V) \tag{16}$$

$$V_{Z_{aT}} = 0.6455 \cdot (0.24 - j2217) = (0.155 - j1431) \ (V) \tag{17}$$

The voltage is complex with the real part very small compared to the imaginary part. Its module is obtained as:

$$|\, V_{Z_{aT}} \,| = 1431 \ (V) \tag{18}$$

The voltage $V_{R_g} = 50\,(\Omega)$ on the generator or amplifier impedance, in order to feed the transmitting antenna, results in:

$$V_{R_g} = (I_T\, R_g) = 0.6455 \cdot 50 = 32.3 \ (V) \tag{19}$$

This way, the voltage V_g from the generator or amplifier must be:

$$V_g = (V_{R_g} + V_{Z_{aT}}) = 1431 + 32.3 = 1463.3 \ (V) \tag{20}$$

The necessary power W_g to produce the transmitting power $W_T = 0.1\,(W)$, result in:

$$W_g = (V_g\, I_T) = 1463.3 \cdot 0.6455 = 944.56 \ (W) \tag{21}$$

It is very important to see the low efficiency of the power supply when a transmitting antenna is very reactive and with no impedance matching. Almost 1 KW to radiate 100 mW. For this reason NIST uses a power amplifier to feed the transmitting short monopole. But it is the only way to feed a wide band short antenna at frequencies lower than 10 MHz. In simulation the voltage using WIPL-D to feed the transmitting antenna is $|\, V_{Z_{aT}} \,| = 1431\,(V)$ and transmitting gain, field strength and power density obtained at the distance $r = 30\,(m)$, are:

$$G_T = 4.77\,(dBi)$$

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$$g_T = 2.99$$

$$E_i = 8.936\,E-2\,(V/m)$$

$$E_z = (-7.269\,E-2\ -\ j5.198\,E-2)\,(V/m)$$

$$H_i = 3.007\,E-4\,(A/m)$$

$$H_x = (-2.165\,E-4\ -\ j2.087\,E-4)\,(A/m)$$

$$P_i = 2.687\,E-5\,(V/m)$$

$$P_y = (2.659\,E-5\ -\ j3.913\,E-6)\,(W/m^2)$$

The wave impedance is obtained as:

$$\mid Z_w \mid = 297.17\,(\Omega), Z_w = (294\ -\ j43)\,(\Omega)$$

At the distance of $r = 30\,(m)$ the far field is not really achieved because the wave impedance is not $Z_w = Z_{00} = 377\,(\Omega)$ but a lower value with a little reactance value. However, the simulation is done according to the field modules. Open circuit voltage V_i for an effective height $H_{eR} = 1.25\,(m)$, results in:

$$V_i = (H_{eR}\,E_i) = 1.25\cdot 8.936\,E-2 = 0.1117\ \ (V) \quad (22)$$

Current module I_R in the receiving antenna equivalent Thevenin circuit for $R_L = 50\,(\Omega)$, results in:

$$I_R = \left(\frac{V_i}{R_L + X_{aR}}\right)\ \ (A) \quad (23)$$

$$I_R = \left(\frac{0.1117}{50 + 2637}\right) = 4.16\,E-5\,(A) \quad (24)$$

The receiving voltage V_{R50}, is obtained as:

$$V_{R50} = (50\cdot I_R) = 50\cdot 4.16\,E-5 = 2.08\,E-3\ \ (V) \quad (25)$$

Receiving antenna factor aF_{R50}, results in:

$$aF_{R50} = \left(\frac{E_i}{V_{R50}}\right) = \left(\frac{8.936\,E-2}{2.08\,E-3}\right) = 42.96\ \ (1/m) \quad (26)$$

The antenna factor AF_{R50} in decibels is:

$$AF_{R50} = (20\,log\,aF_{R50}) = 32.66\ \ (dB/m) \quad (27)$$

This is a pure imaginary antenna factor. If an antenna factor could be real, complex or imaginary, the area of the receiving antenna could get the same characteristics because the power on the load impedance R_{L50} could be complex. Using the classical equation:

$$A_{eR} = \left(\frac{W_R}{P_i}\right)\ \ (1/m) \quad (28)$$

The power at the calibrated receiver input, results in:

$$W_{R50} = (R_L\cdot I_R^2) = 50\cdot (4.16\,E-5)^2 = 8.65\,E-8\ \ (W) \quad (29)$$

And the effective area, results in:

$$A_{eR} = \left(\frac{W_R}{P_i}\right)\ \ (m^2) \quad (30)$$

$$A_{eR} = \left(\frac{8.65\,E-8}{2.687\,E-5}\right) = 3.22\,E-3\,(m^2) \quad (31)$$

Numerical receiving antenna gain, according to Schelkunoff and Friis, results in:

$$g_R = \left(\frac{4\,\pi}{\lambda^2}\right) A_{eR} = \frac{4\,\pi}{100^2}\,(3.22\,E-3) = 4.05\,E-6 \quad (32)$$

The receiving antenna gain G_R in decibels, results in:

$$G_R = 10log\left(\frac{4\,\pi}{\lambda^2}\right) A_{eR} = -53.93\ \ (dBi) \quad (33)$$

The transmission loss a_w in the radio link is obtained, as:

$$a_w = \left(\frac{W_R}{W_T}\right) \quad (34)$$

$$a_w = \left(\frac{8.65\,E-8}{0.1}\right) = 8.65\,E-7 \quad (35)$$

The power transmission loss or site attenuation A_w in decibels, results in:

$$A_w = 10\,log\,a_w = -60.63\ \ (dB) \quad (36)$$

Free space A_{FS} in decibels, results in:

$$A_{FS} = 10\,log\left(\frac{\lambda}{4\,\pi\,r}\right)^2 = -11.53\ \ (dB) \quad (37)$$

Gain and losses relationship, according to Schelkunoff and Friis [3], results in:

$$G_T\ +\ G_R = 4.77\ +\ (-53.93) = -49.16\ \ (dB) \quad (38)$$

$$A_w\ -\ A_{FS} = -60.63\ -\ (-11.53) = -49.10\ \ (dB) \quad (39)$$

Friis radio link power budget is fullfilled.

Scattering gain in dBi is calculated by software WIPL-D, as:

$$G_s = -18.33\ \ (dBi) \quad (40)$$

Numerical scattered gain g_s, results in:

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$$g_s = 1.47\,E-2 \tag{41}$$

Scattering area is obtained by the isotropic radiator area A_{eo} and the numerical scattering gain g_s, as:

$$A_{es} = \left(\frac{\lambda^2}{4\,\pi}\right) g_s = 11.70\ \ (m^2) \tag{42}$$

Transmitting antenna effective area A_{eT}, is obtained this way, knowing its numerical gain g_T, or:

$$A_{eT} = \left(\frac{\lambda^2}{4\,\pi}\right) g_T = 2379.37\ \ (m^2) \tag{43}$$

Relation between areas and gain, according to Schelkunoff and Friis [3] are:

$$\left(\frac{A_{eT}}{g_T}\right) = \left(\frac{2379.37}{2.99}\right) = 795.8 \tag{44}$$

$$\left(\frac{A_{es}}{g_s}\right) = \left(\frac{11.70}{1.47\,E-2}\right) = 795.9 \tag{45}$$

$$\left(\frac{A_{eR}}{g_R}\right) = \left(\frac{3.22\,E-3}{4.05\,E-6}\right) = 795.1 \tag{46}$$

All cases are giving practically the same results. At this example of $f = 3\,(MHz)$ in the radio link with a transmitted power $W_T = 100\,(mW)$ the received voltage is $V_{R50} = 2.08\,E-3\,(V)$ or $V_{R50} = -26.82\,(dBV)$ or in power $W_{R50} = 8.65\,E-8\,(W)$ or $W_{R50} = -70.63\,(dBW)$ and the antenna factor $AF_{R50} = 32.66\,(dB/m)$. According to the reciprocity principle (Schelkunoff and Friis) is possible to calculate the transmitting antenna factor aF_{T50} [10], to be:

$$aF_T = \left(\frac{1}{\lambda}\right)\left(\frac{4\,\pi\,Z_w}{R_L\,g_T}\right) = 4.99\,E-2\ \ (1/m) \tag{47}$$

in decibels:

$$AF_T = 20\,log\left(\frac{1}{\lambda}\right)\left(\frac{4\,\pi\,Z_w}{R_L\,g_T}\right) = -13.02\ \ (dB/m) \tag{48}$$

For this example the relationship between factors, areas and gain for the monopole antennas for $H_T\,, H_R = 2.5\,(m)$, results in:

$$\left(\frac{aF_{R50}}{aF_{T50}}\right) = \left(\frac{42.96}{4.99\,E-2}\right) = 860.92\ (58.7\,dB) \tag{49}$$

$$\left(\frac{A_{eT}}{A_{eR}}\right) = \left(\frac{2387.32}{3.22\,E-3}\right) = 741403.73\ (58.7\,dB) \tag{50}$$

$$\left(\frac{g_T}{g_R}\right) = \left(\frac{2.99}{4.05\,E-6}\right) = 738271.6\ (58.7\,dB) \tag{51}$$

These relationship are giving the same result in dB. This means the radio link was calculated accurately. An important thing to know is, in the case of the short antennas, the difference between identical antennas characteristics over ground are extremely different and not only 6 dB like in the case of resonant and perfectly matched identical antennas [10]. Here is shown that the equation 7 in the Standard IEEE-ANSI C63.5-2004 cannot be used because the factors, area and gain are not the same for identical antennas when they are operating over perfect ground. Different procedure must be used. NIST (Technical Note 1347) [12] have not calculate all the parameters obtained here in order to know the behavior of both antennas and their characteristics.

f	X_{aR}	aF_{50}	AF_{R50}	Z_{aR}	aF_{R50}	AF_{R50}
MHz	(Ω)	$(1/m)$	(dB/m)	(Ω)	$(1/m)$	(dB/m)
1.0	8038	128.61	42.19	0.027-j7969	127.39	42.10
1.5	5359	85.74	38.66	0.060-j5306	84.75	38.56
2.0	4019	64.30	36.16	0.107-j3972	63.29	36.03
3.0	2679	42.87	32.64	0.241-j2637	42.96	32.66
5.0	1607	25.71	28.20	0.668-j1555	24.88	27.92
7.5	1072	17.15	24.69	1.500-j1004	16.13	24.15
10.0	804	12.86	22.19	2.660-j 718	11.56	21.26

Table I
Results of antenna factor AF_{R50} for short monopole antennas as a function of frecuency in MHz. Columns 2,3 y 4 calculated by NIST, columns 5,6 y 7 calculated for a radio link with a tradicional procedure shown previously for $f = 3\,(MHz)$.

Doing the same simulation for other frequencies the results are presented in Table I. In this table it can be shown that the results obtained are practically identical to that obtained by NIST.

VIII. Transmitting Antenna Factor Definition

Transmitting antenna factor aF_T was not defined as the receiving antenna factor aF_R, or:

$$aF_R = \frac{E_i}{V_R} = \left(\frac{P_i\,Z_{oo}}{W_R\,R_L}\right)^{1/2} = \left(\frac{Z_{oo}}{A_{eR}\,R_L}\right)^{1/2}\ (1/m) \tag{52}$$

However, is possible to determine the transmitting antenna factor by means of the Power Reciprocity Principle according to Schelkunoff and Friis [3].

According to the Receiving antenna factor definition:

$$aF_R = \frac{E_i}{V_R} = \left(\frac{P_i\,Z_{oo}}{W_R\,R_L}\right)^{1/2} = \left(\frac{Z_{oo}}{A_{eR}\,R_L}\right)^{1/2}\ (1/m) \tag{53}$$

It is possible to determine the relation between the receiving numerical antenna factor aF_R to the receiving antenna effective area A_{eR}, in the far field when the wave impedance $Z_w = Z_{oo} = 120\,\pi \simeq 377\,(\Omega)$, or:

$$\boxed{aF_R = \left(\frac{Z_{oo}}{A_{eR}\,R_L}\right)^{1/2}\ (1/m)} \tag{54}$$

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Receiving antenna effective area, in the far field, results in:

$$A_{eR} = \frac{\lambda^2 \, g_R}{4\,\pi} \; (m^2) \tag{55}$$

This way, is possible to determine the relation between the receiving numerical antenna factor aF_R to the receiving antenna numerical gain g_R in the far field, or:

$$\boxed{aF_R = \frac{1}{\lambda}\left(\frac{4\,\pi\,Z_{oo}}{g_R\,R_L}\right)^{1/2} \; (1/m)} \tag{56}$$

Power reciprocity principle presented by Schelkunoff and Friis [3], is expressed as:

$$\frac{A_{eT}}{g_T} = \frac{A_{eR}}{g_R} \tag{57}$$

Or:

$$\frac{A_{eT}}{A_{eR}} = \frac{g_T}{g_R} = \left(\frac{aF_R}{aF_T}\right)^2 \tag{58}$$

Transmitting antenna factor results in:

$$aF_T = aF_R\left(\frac{g_R}{g_T}\right)^{1/2} \; (1/m) \tag{59}$$

$$aF_T = \left(\frac{Z_{oo}}{A_{eR}\,R_L}\,\frac{g_R}{g_T}\right)^{1/2} \; (1/m) \tag{60}$$

$$\boxed{aF_T = \frac{1}{\lambda}\left(\frac{4\,\pi\,Z_{oo}}{g_T\,R_L}\right)^{1/2} \; (1/m)} \tag{61}$$

This equation is exactly the same as for the receiving antenna factor but instead of the numerical gain g_R for the transmitting antenna the numerical gain g_T must be used. At the same time, it is seen that these equations are that indicated by the Federal Communication Commission (F.C.C.) to calculate the antenna factors if the space intrinsic impedance $Z_{oo} = 120\,\pi = 377\;(\Omega)$, wavelength in (m) and a load resistance $R_L = 50\,(\Omega)$ must be used. In dB, it results in:

$$\boxed{AF_R = 19.77 \; - 20\,log\,\lambda \; - 10\,log\,g_R \; (dB/m)} \tag{62}$$

For a receiving antenna.

$$\boxed{AF_T = 19.77 \; - 20\,log\,\lambda \; - 10\,log\,g_T \; (dB/m)} \tag{63}$$

For a transmitting antenna.

As a function of space intrinsic impedance $Z_{oo} = 120\,\pi = 377\;(\Omega)$, frequency in MHz and a load resistance $R_L = 50\,(\Omega)$, results in:

$$\boxed{AF_R = -29.78 \; + 20\,log\,f_{MHz} \; - 10\,log\,g_R \; (dB/m)} \tag{64}$$

For a receiving antenna.

$$\boxed{AF_T = -29.78 \; + 20\,log\,f_{MHz} \; - 10\,log\,g_T \; (dB/m)} \tag{65}$$

For a transmitting antenna.

These equation are valid for a radio link in free space or over a perfect ground using the corresponding gain obtained in the indicated environment. Over perfect ground the maximum gain obtained for a theoretical half wave dipole antenna is $G_T = 8.15\,(dBi)$ or very close to this value in an actual environment and $G_R = 2.15\,(dBi)$ for a receiving half wave antenna at practically any height over perfect ground [10]. Around $R_{aT} = R_{aR} = 73\,(\Omega)$ is obtained for the radiation resistance of a resonant dipole. ($R_{aT} = R_{aR} = 70\,to\,73\,(\Omega)$ in practical thin dipoles.

In the case of a theoretical quarter wave monopoles over perfect ground maximum gain for a transmitting antenna is $G_T = 5.15\,(dBi)$ at zero elevation angle and $G_R = -0.85\,(dBi)$ for the receiving antenna [10]. Around $R_{aT} = R_{aR} = 34\,to\,36\,(\Omega)$ of a radiation resistance is obtained in resonance for thin monopoles.

In conclusion it was demostrated that the antenna parameters in a radio link over perfect ground have a difference of 6 dB in favor of the transmitting antenna for perfect resonant and matched antennas, in the maximum radiation [10]. This is valid for any identical antenna used in the radio link. For not perfectly matched antennas this difference is even larger, as demostated previously, in this paper.

IX. Conclusions

The comments that have been presented here show that a radio link, in free space or over perfect ground, using any kind of antennas, can be verified using the Friis equation and achieve the power budget and the power reciprocity principle in order to be sure that the radio link is working properly. No artificial factors are needed to obtain this result if the proper antenna gain is used [7],[8]. In the case of a quarter wave monopole antenna its gain over a perfect absorbing surface has a theoretical gain of $G_T = -0.85(dBi)$ (theoretically a real monopole). Over a perfect reflective surface its image increases its length to a half-wave (a real dipole), that in free space has a gain of $G_T = 2.15(dBi)$. For this reason, a called monopole over perfect ground needs to only cover the half spherical space over ground and this increases its gain additionally by 3 (dB) achieving the well known gain of $G_T = 5.15(dBi)$ and maintaining its radiation resistance in resonance $R_{aT} \simeq 36(\Omega)$, because mutual effects are not available. Dr Wolff made a perfect explanation of a Tx quarter-wave monopole antenna characteristics showing that its effective area is twice the area of a half-wave dipole antenna

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in free space and its logical gain $G_T = 5.15[dBi]$. However, he said nothing about the characteristics of Rx quarter wave monopole antenna whose effective area is half the area of a half-wave dipole in free space and its logical receiving gain $G_R = -0.85[dBi]$. This means 3 (dB) larger gain of a half-wave dipole antenna in free space who needs to cover all the spherical area with its radiated energy. This problem was solved in the thirthie's in the golden AM BC era. In the receiving case its effective area is half that of the half-wave dipole in free space and from it, according to Schelkunoff and Friis, its receiving gain is $G_R = -0.85(dBi)$, a true monopole without image. At the same time, any receiving antennas in the receiving role work like in free space, because no transmitting energy is arriving at its image if the surface is not transparent. Thus, it works practically independent of its height over ground and of its distance from the transmitting one. Of course, in scattering the Rx antenna works practically like a Tx antenna and its reradiation or scattering depends on its height over ground and with its image assistance. This also, is verified in the case of the monopole-dipole radio link where the gain of the monopole is G_T = 5.15 (dBi) and the dipole over ground has a receiving gain, as was determined previously, of G_R = 2.15 (dbi), practically constant like in free space. In all case analized, the power budget and the power reciprocity principle are fulfilled perfectly well without changing the natural antenna gains and showing the perfect radio link work. The Tx antenna gain, well known since the thirties, add 6 db at its gain compared to the gain of the same antenna in free space. This depends of the image effect like in the monopole antenna case. These results have been corroborated experimentally in the RF spectrum in MF, HF, VHF and UHF confirming that the Rx antenna in the receiving role works without the image effect or like in free space. It was determined that in the short monopole antenna case the difference between identical antennas in transmission and reception is extremely greater than in the case of resonant and well matched antennas and not only 6 dB. Here it is shown that over perfect or natural ground identical antennas have always different characterisitics as factor, area and gain. It is also important to know that: **the antenna area A_{eT} A_{eR} and gain g_T g_R are parameters valid accurately in far field $r \gg \lambda$ when the wave impedance Z_w is really $Z_{00} = 120\pi$ and the effective length L_{eR} or height H_{eR} and the antenna factor aF_T aF_R is a parameter inherent of the antenna, for this reason they are practically constant from the distance or height over ground**. However, these parameters can be related between them in the far field.

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Real-Time Face Feature Reshaping without Cosmetic Surgery

By Jagruti Rameshbhai Boda & Dr. Dipali Kasat

Abstract- In the contemporary world today, computer vision applications make use of 4G technology and high-definition (HD) video calling on mobile phones. People frequently utilize 4G video calling to communicate with friends and family. The technology is capable of projecting minute elements from the real world, such as background, facial features, and behavior, among other things. We developed a video processing system that lets users alter the shape and look of facial features such as the eyebrows, eyes, nose, lip, jaw, and chin. Our work improves users' facial look during live 4G video calls; the user sees the desired modified face feature in real-time, as if in a virtual mirror, and can then use it. Abstract environment.

Keywords: *face beautification, face morphing, face feature reshape, real-time processing, video processing.*

GJCST-H Classification: *DDC Code: 371.33523 LCC Code: LB1044.75*

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Real-Time Face Feature Reshaping without Cosmetic Surgery

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I. Introduction

Human faces represent detailed sources of information such as identity, age, gender, intention, and reaction (Response of expression). Also, humans have a great inclination towards their face attractiveness [8]. Thus, there exist many cosmetic surgeries to improve face attractiveness by modifying face appearance, face color, and shape. However cosmetic surgery is more expensive and painful, therefore only rich people can afford it [7] [9] [10]. Extensive research is being carried out in this field for improving facial aesthetics. But face aesthetics is subjective. Thus, we need some solution that can generate or predict face appearance before surgery [13] [14]. The computer vision domain provides research for the improvement of facial aesthetics in the digital domain which is virtual improvement in facial aesthetics in images and video. We proposed a real time face feature reshaping technique for eyes, eyebrows, jaw, chin, nose, and lips. So that user can see their manipulated appearance in real-time.

II. Previous Work

Face detection is the most important phase in computer vision problems. Michael J. Jones Paul Viola [30] proposed a face detection framework. We categorized the face morphing method into two types: Model-based and non-model-based methods. The model-based method includes various face shape models such as the Active appearance model [24] [29], the Active Shape model [24], the Constrained Local Model [21], the 3D morphable face model [2-3][8][18] and many more. The base face model [19] and surrey face model [19] are the most widely used 3D face model. The face shape model is constructed from the face, morph the model then fits onto the original face. The model construction and fitting are more difficult tasks that required lots of computation. The model-based method provides a good result for real-time processing so widely used in image and video morphing. D. Kasat et. al [9] proposed a real-time morphing system that morphs the face feature in real-time using a Kinect sensor to stream input video. The system was able to morph the face features such as the jaw, chin, nose, mouth, and eyes in real-time. The Active appearance model-based method and moving least square method [35] are used for image deformation. The system degraded the performance in some illumination conditions and produce delay. Yuan Lin et. al [3] proposed a face-swapping method that does not require the same pose and appearance of the source and target image. The 3D model-based approach is used therefore allowing any render angle of a pose. The 3D model is constructed from the user's uploaded image and the swapping method is used to replace the character of the face. The result is accurate when the target object has nonfrontal faces. But the method is not able to handle large illumination differences between the source image and target image. A non-model-based method such as face morphing using a critical point filter [6] finds the critical value of the face and modifies that value using a critical point filter (CPF). The filter can filter image properties such as depth value, color, and intensity. The method is developed for two face images of the frontal face. The landmark points used are few to curtail the processing time required for a greater number of landmarks and large image size.

III. System Overview

This system is implemented using OpenCV with python 3.7.0. The main objective of this work is to reshape individual features of the face like eyebrows, eyes, nose, lip, chin, jaw, etc. in real-time with minimum delay. An image deformation algorithm is thus applied only on the face area of window size 200 × 200. The window size is fixed to reduce the response delay. The

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system flowchart is illustrated in figure 1. The working of the system begins with the capture of the real-time video using the device camera. As input to the system, we took the RGB video stream captured by the Sony Laptop (device) front camera at a width of 900 pixels, and convert the RGB video frame into a grayscale image for image deformation operation. We assumed that there is only 1 person (referred to as the actor) in front of the device camera, and take as input a set of face shape modification parameters from the user. Then, we detect the face using a face detection algorithm and identify the face features to localize the certain key feature point. Object detection using Histogram of Oriented Gradients with Linear SVM method [36] is being used to detect facial landmarks. Firstly, OpenCV is used to detect the face from the given input video frame, then pre-processed the image to maintain equal size with a width of 900 pixels.

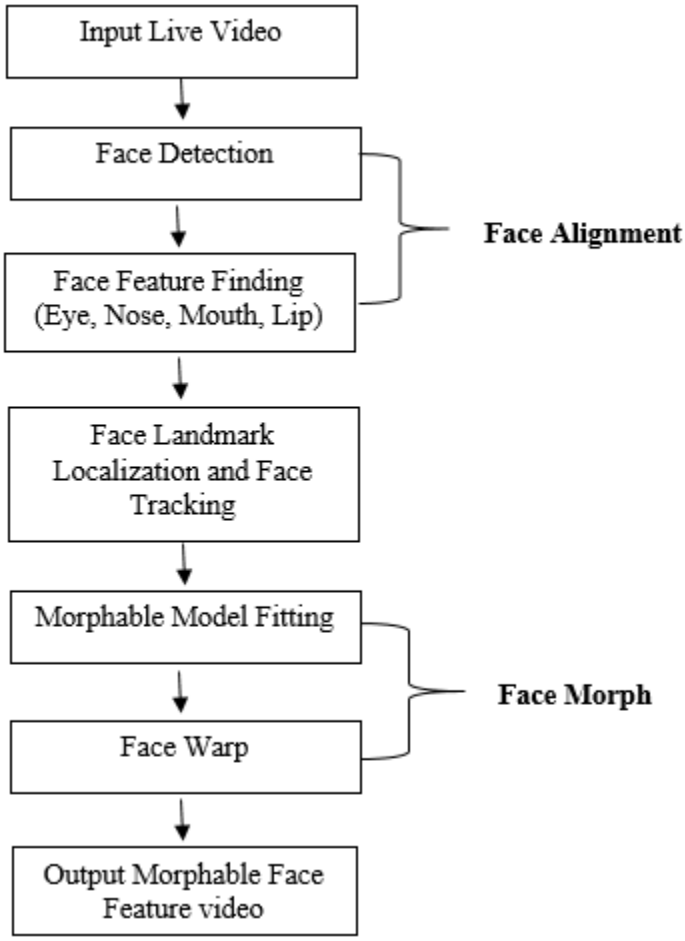

Fig. 1: System Diagram of Proposed System

Therefore, we converted each video frame to have an equal size. The resolution of the input image allows us to detect more depth of video frames. In our system, we used 68 Primary and Secondary landmark points [33] as shown in figure 2. The landmark points are used to find the exact position of the face feature and used to reshape the features. The system extracts a set of x/y coordinates on the input face. These face landmark points are fed into the image deformation method that reshapes the face parameter as per the user requirement provided as input. The Facial feature is the lip, Right eyebrow, Left eyebrow, Right eye, Left eye, Nose, Jaw, and chin. Kazemi and Sullivan [33] proposed a One Millisecond Face Alignment with an Ensemble of Regression Trees based method used for face landmark detection. We used this method for accurate landmark detection on the user's face. We used a pre-trained facial landmark detector to

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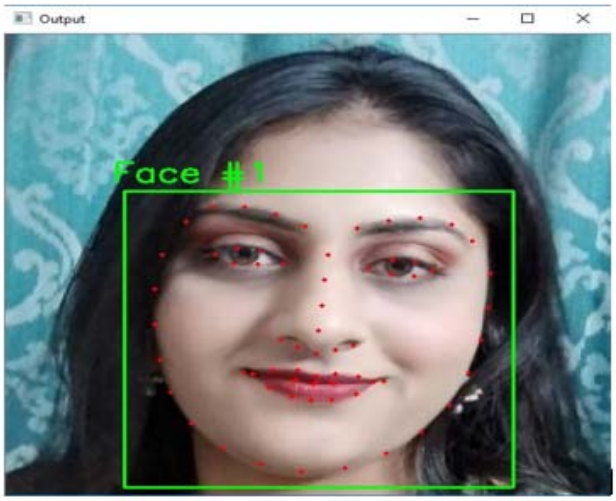

Fig. 2: Visualizing the 68 Facial Landmark Coordinates

estimate the location of 68 (x, y)-coordinates that map to facial structures on the face. The indexes of the 68 coordinates can be visualized in figure 2. We can see that the red dots mapped to specific facial features, including the jaw, chin, lips, nose, eyes, and eyebrows. The end result detected facial landmarks in real-time with high accuracy predictions. The Moving Least square (MLS) [35] method is used to reconstruct a surface from a set of landmark points. MLS created deformations using affine similarity, and rigid transformations. These deformations are realistic and give the user the impression of manipulating the facial features in real-time with high speed. The method generates a new image frame by warping the corresponding pixels of the source points to the positions of the destination points. Image deformation performs in each and every video frame and generates an output video in real-time. The output from the system is live and a morphed RGB video stream where the required face shape modifications are performed.

Fig. 3: Original image (left) and its deformation using the rigid MLS method (right). After deformation, the face eyebrow is reshape

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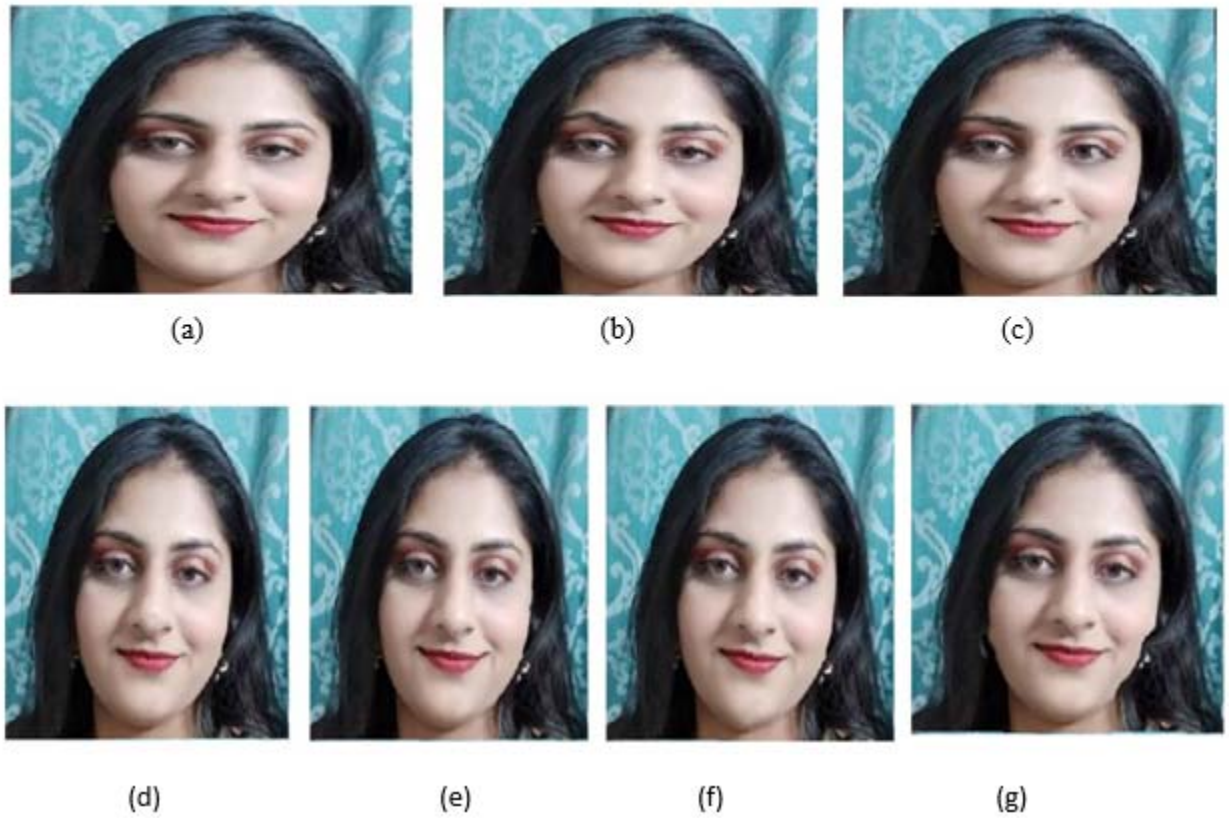

Fig. 4: (a) Original image (b) Left eyebrow is reshape (c) Right Eye Reshape (d) Nose Reshape (e) Lip Reshape (f) Chin Reshape (g) jaw Reshape

IV. Result Analysis

The result of the proposed work is projected in Figure 4 in which various feature such as eyebrow, eye, nose, lip, chin, and jaw are reshaped as per user requirement. The reshaped feature can be deployed by the common use for various applications such as in plastic beauty surgery in which user can visualize their face before cosmetic surgery. The user can change various parameters in real-time and visualize their face with a modified face feature. The system can also be used for face beautification applications, to have some fun with friends, to share on social media, and capture memorable moments. The best thing is we edit in real-time without using any external device. The system was evaluated for various profile face such as left, frontal, and right profile face. We also analyzed the time required to produce the output video. The result shows that in left and right profile face required more time to produce output video. Table 1 shows the Response time required to generate an output video of ten video frames in a millisecond. Figure 5 shows the time analysis graph of various profile faces.

V. Comparison with Previous Work

Work done by D. Kasat et al. [9], in which we can see similar effects (as shown in Figure 8) on face feature are reshaped using Kinect sensor for input video.

Table 1: Response Time for Output Video Frame in Various Profile Face

Video Frame	Response Time in Left Profile Face	Response Time in Front Profile Face	Response Time in Right Profile Face
1	34	26	34
2	33	25	33
3	25	24	26
4	26	25	24
5	27	24	25
6	25	23	24
7	26	24	25
8	24	25	24
9	25	22	25
10	23	24	23

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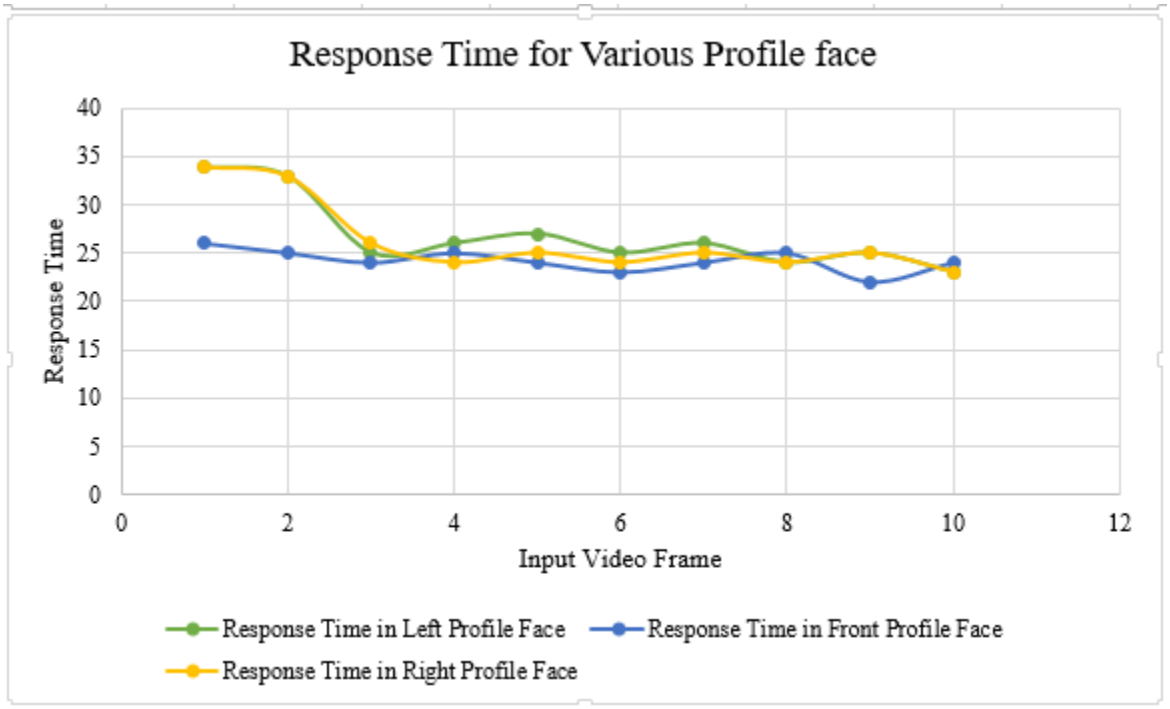

Fig. 5: Response Time for Various Facial Positions

Table 2: Average Response Time for Output Video Frame in Various Illumination Conditions

Video Frame	Response time in Dark Illumination	Response time in Normal Illumination	Response Time in Light Illumination
1	48	26	27
2	23	22	21
3	25	23	25
4	25	24	24
5	29	29	23
6	27	27	23
7	30	25	25
8	28	24	29
9	24	27	24
10	28	30	24

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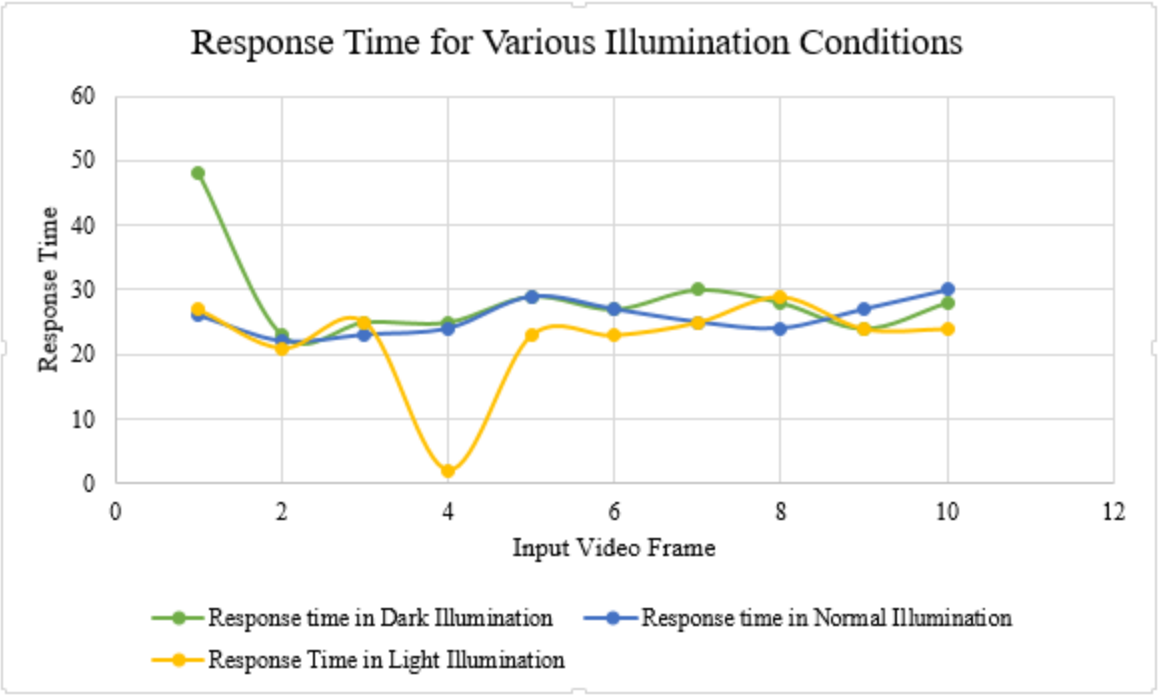

Fig. 6: Time Graph of Various Illumination Conditions

In our works, (as shown in Figure 4) the system allows users to reshape individual face parameters in real-time without using any external device with less delay. In the existing system, we need to configure and connect the Microsoft Kinect sensor with the device therefore, the system portability is less compared to the proposed system. The quality of output and input images compared with Structural Similarity Measurement Index (SSIM).

The SSIM value of an existing and proposed system is shown in table 3. The existing system provides good quality results because they used Microsoft Kinect sensor for input video that provides a 3D view and depth of capture image. In our system, we used a device front camera that is enough to be capable good quality video. The graphical representation of the SSIM value is shown in figure 9. The comparison of the original face and deformed face with SSIM value shows in figure 8 and figure 9.

Table 3: SSIM Value of Existing and Proposed System SSIM Value Existing System Proposed System

SSIM value	Existing System	Proposed System
Result 1	0.73	0.73
Result 2	0.89	0.77
Result 3	0.80	0.77
Result 4	0.74	0.74

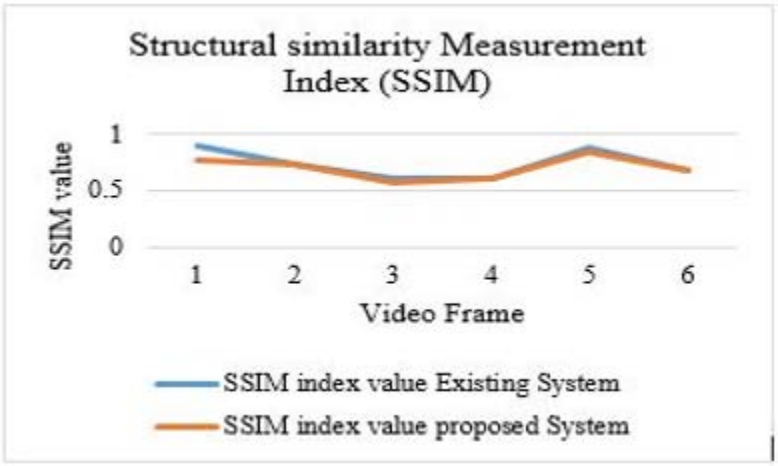

Fig. 7: Structural Similarity Measurement Index Analysis

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Fig. 8: Existing System (a) Original Image (b) Morphed Image with SSIM=0.73

Fig. 9: Proposed System (a) Original Image (b) Morphed Image with SSIM 0.73

VI. Conclusion

A real-time face feature reshaping for video sequence is introduced which allows reshaping of specific features like eyebrow, eye, nose, lip, jaw, and chin of the face which cannot be achieved by existing morphing technique. We proposed for the first time, a real-time video morphing system without any use of an external device. Our system provides portability that can be in entertainment applications, games, film production, medical, and beautification fields. With full flexibility and good accuracy, the system allows to reshape face features in real-time. The comparison with the existing method using the SSIM index qualifies the quality of generated output. Also, the analysis of the time required for the output of various profile face and illumination condition justify the proposed system. In the future, we will make an expert system that is used in medical applications to visualize modified faces before plastic surgery.

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A Metaverse Maturity Model

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Keywords: *metaverse, virtual world, maturity model, decentraland.*

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A Metaverse Maturity Model

Markus Weinberger [α] & Daniel Gross [σ]

Abstract- The idea of the Metaverse as the next iteration of the internet gets increasing attention. As the development is still in its infancy, maturity assessments of the Metaverse in general and its constituting virtual worlds could provide critical input to guiding research and development as well as investments. Based on a scientific definition of the Metaverse, eight core attributes for its virtual worlds are extracted. For each of these attributes, five maturity levels are defined. Thus, a Metaverse maturity model with eight attributes and five maturity levels is proposed. This model is then applied to assess the maturity of the virtual world Decentraland. This pilot assessment reveals that attributes mainly depending on strategic decisions reach higher maturity levels than those mainly depending on technological aspects. This indicates a solid strategic dedication of Decentraland to the Metaverse vision.

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I. Introduction

In the past year, the term Metaverse got great attention [1]. At the same time, it is evident that its full implementation as an interconnected web of virtual worlds (VW) [2] is still far in the future [3]. The Metaverse can be considered the successor to the mobile internet, much like the mobile internet is regarded as the successor technology of the internet. While the mobile internet leverages existing infrastructure, it fundamentally changes how, where, when, and why we access the internet. A similar change can also be expected from the Metaverse. With emerging technologies, even with a good understanding of the field, it is often unclear what further innovations and inventions are needed to reach mass application [4].

Both science and economy require tools to assess the development status of the Metaverse and the virtual worlds comprising it. The former have to identify gaps in research and development to create a roadmap. The latter needs to identify promising development approaches and comparatively mature virtual worlds to make successful investments.

This study aims at addressing this need by presenting a maturity model for the assessment of virtual worlds. Based on a scientific definition of the Metaverse [5], eight core attributes are identified, which would make a complete Metaverse. For each of these core attributes, five maturity levels (ML) are defined.

The Metaverse core attributes derived from the definition are presented in Section 2. Each of the core attributes is explained in Section 3, which includes a depiction of the corresponding five maturity levels, too. Thus, the complete maturity model can be presented in Section 4, and in Section 5, the results of an exemplary application to the virtual world Decentraland are explained. Finally, a discussion is included in Section 6.

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II. Metaverse Definition and Core Attributes

The following definition of Metaverse will be analyzed in order to identify core attributes making a complete Metaverse: "The Metaverse is an interconnected web of ubiquitous virtual worlds partly overlapping with and enhancing the physical world. These virtual worlds enable users represented by avatars to connect and interact with each other, to experience and consume user-generated content in an immersive, scalable, synchronous, and persistent environment. An economic system provides incentives for contributing to the Metaverse." [5]

The notion that many virtual worlds make the Metaverse indicates that virtual worlds should be the object of maturity assessments.

The text passages of the definition translate into Metaverse core attributes as depicted in Table 1.

Table I: Definition Passages and Core Attributes

Definition Passage [5]	Metaverse Core Attribute
"… an interconnected web …"	Interoperability
"… partly overlapping with and enhancing the physical world."	Physical and digital coexistence
"…user-generated content…"	User-generated content
"…immersive,…"	Immersive realism
"… scalable, …"	Scalability
"…synchronous …"	Synchronicity
" … and persistent …"	Persistence
"An economic system …"	Economy

III. Explanation of Core Attributes and Maturity Levels

This Section will explain the eight Metaverse core attributes and the corresponding maturity levels.

a) *Persistence*

Persistence means that the state of the virtual world is maintained indefinitely if it is not changed by a user. Specifically, this means that there are no pauses, restarts, or even an end [6]. For the persistence of a virtual platform, it is essential that the user always has access and that entering or leaving has no influence on the virtual world.

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A virtual world on maturity level 1 would not be persistent. It could be turn-based and have frequent resets. ML 2 requires a VW to be accessible at almost all times, with planned resets or updates taking place sometimes. On ML 3, the VW has sometimes resets or needs to halt for updates. ML 4 means the platform is in general persistent with rare exceptions. ML 5 would mean a fully persistent virtual world.

b) Synchronicity

This attribute indicates whether users can communicate and interact with each other in real-time and whether this can be experienced worldwide or just limited to regions.

Synchronicity is fundamental to smooth social interactions. It depends to a large extent on the latency of network connections [7].

Synchronicity ML 1 corresponds to a VW without any online presence, as it is known from offline computer games. ML 2 requires real-time interactions between users, but within a limited VW space and with a limited number of users. ML 3 means users can interact live, but only within regions of the physical world. ML 4 allows all users to interact in real-time with no general limits in regions or numbers of users, but with rare exceptions when latency increases or communication pauses. ML 5 is equivalent to ML 4 without pausing or latency problems.

c) Scalability

The vision of the Metaverse comprises the idea that an unlimited number of users can experience virtual worlds simultaneously [8]. This attribute is strongly related to the computing power of the platforms running the virtual worlds as well as the bandwidth of connections [7].

The number of users, who can simultaneously use a virtual world, will measure scalability in this context. This is meant without splitting the virtual world into different instances in order to limit the number of users per instance. The relation between maturity levels and number of users can be seen in Table 2.

Table II: Scalability Maturity Levels

Maturity Level	No. of simultaneous users in the virtual world (not split into different instances)
1	Up to 10
2	Up to 250
3	Up to 1000
4	Up to 10,000
5	No limit

d) Physical and Digital Coexistence

This core attribute relates to interfaces connecting the virtual and physical world. Important aspects are the means for users to control their avatars and to experience the virtual world. In addition, many other interfaces can be taken into account, which connect and mirror physical objects to virtual objects in line with the idea of digital twins [9], or connections of the economic systems in the virtual and physical world, e. g., virtual currencies that can be exchanged to fiat currencies of the physical world.

The five maturity levels related to physical and digital coexistence correspond to the number of available interfaces. They are defined as follows. ML 1 represents a purely virtual world with no interfaces to the physical world beyond screen and controller-based means for the user to control an avatar. ML 2 has one advanced interface, such as virtual reality capability or a transferable currency. The third maturity level requires the VW to have several interfaces. On ML 4, in general, changes in the physical world can influence the virtual world and vice versa. ML 5 means the physical and virtual world are continuously interfacing.

e) Interoperability

While the last core attribute is related to interfaces between the physical and virtual worlds, interoperability refers to interfaces between the virtual worlds constituting the Metaverse. This is about the ability to exchange data between different VWs, enabling, for example the use of one avatar with its accessories in many or even all virtual worlds or trading virtual assets between virtual worlds. Interoperability is an essential precondition forming one Metaverse consisting of many virtual worlds [2].

The maturity levels for this core attribute relate mainly to the number of transferable components and the number of interconnected virtual worlds. ML 1 describes a virtual world without any interfaces to other VWs. A virtual world with ML 2 regarding interoperability has interfaces to make one component transferable, e. g. avatars or assets. ML 3 requires interfaces for several components, and ML 4 means that VWs have interfaces to transfer relevant components but might not be connected to all VWs in the Metaverse. This might be the case when concurring systems or interface standards evolve. On ML 5, finally, there is full interoperability between all virtual worlds.

f) User-generated Content (UGC)

Even the technologically most advanced virtual world needs to have attractive content to attract users. Such content could, for example be games, events, exhibitions, concerts, and many more. But, also assets, avatar-skins, architecture etc. could be seen as relevant content [9]. No single company will be able to compete against a platform that allows its users to create content and shape the virtual world.

Maturity level 1, in this regard is a VW that does not allow UGC. On ML 2 users have minimal possibility to change the virtual world with UGC still not being in the vendor´s strategic focus. ML 3 refers to a world where users can create content, and this plays an important role. ML 4 refers to the situation in which UGC is possible in a large variety and complexity, and where

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the monetization of UGC is directly possible in the VW. ML 5 means that the users actually create the VW building on a given base environment. Every aspect of UGC can be monetized.

g) Economy

A fully functioning economy will be an essential aspect of the Metaverse [10]. This is true as it is the precondition to incentivize the users to create content [11] and to drive investments into a virtual world. Such an economy requires elements like, for example a virtual currency, marketplaces, or ownership registries for assets or land.

Regarding economy maturity, level 1 means that the VW has no economy. In-app or in-game purchases might be possible. A virtual world reaches ML 2 by having aspects of a virtual economy, including a virtual currency. Fiat money can be exchanged into the virtual currency. ML 3 requires an economy with self-regulating markets. Fiat money purchases are possible. ML 4 adds the aspect of virtual jobs and a job market enabling the generation of a physical world income. On ML 5, finally, a fully developed virtual economy with self-regulating markets blends with the physical economy.

h) Immersive Realism

Immersive realism is the degree to which a user feels to be drawn into the virtual world. This has aspects related to content, experiences, and interactions in a VW similar to a book or a movie. In addition, there are technical aspects to serve human sensors with optical, acoustic and haptic information [3]. With respect to this core attribute, the latter are evaluated to determine the maturity level, as they can be analyzed more objectively.

A virtual world on ML 1 in this topic does hardly provide any feeling of immersion. For example, conversations are text chat based, and avatars do not show any facial expressions. ML 2 provides little immersive experience, e.g., avatars provide a feeling of individual presence, users can act freely, and there is voice chat available. ML 3 comprises individual avatars with gestures and facial expressions increasing the immersive feeling in avatar interactions. Virtual reality (VR), 3D audio, and motion tracking capabilities foster this experience. ML 4 adds haptic feedback and high-end VR. And ML 5 represents a VW with a high level of realism, which serves all human senses, thus creating an immediate, immersive experience which can hardly be distinguished from the physical world.

IV. The Metaverse Maturity Model

After explaining the Metaverse core attributes and the characteristics of the corresponding maturity levels in Section 3, this Section presents the complete Metaverse maturity model. It is depicted in Table 3.

For the visualization of assessment results, radar charts are proposed. They are appropriate for multivariate data with more than three variables which correspond to the core attributes [12].

V. Maturity Assessment of Decentraland

An assessment of the virtual world Decentraland using the presented Metaverse Maturity Model is shown in the following. Decentraland is a virtual world using the Ethereum blockchain as a decentral backbone [13]. Furthermore, it is governed by a decentralized autonomous organization (DAO), involving users and contributors in important decisions related to the virtual world [14].

a) Evaluation

In Decentraland, various items are persistent in the sense they exist independently from the presence or connection of a specific user. For example, parcels of land in the VW, experiences (so-called scenes in Decentraland), or assets are persistent. Some assets related to avatars, e. g. clothing, are persistently saved to the user´s account. The same is true for the in-world currency called MANA [15]. According to Table 3, this high level of persistence is rated to be at ML 4.

In general, Decentraland is a real-time virtual world with moderate latency requirements. The ability for a user to interact with other users on the other hand, depends on so- called realms and islands. Decentraland is powered by several content servers, each providing realms. Within a realm, a cluster of connected avatars is called an island. Islands change dynamically as avatars join or leave depending on the proximity. Only users within the same realm and island can interact, and there is a limited number of users permitted per island [16]. But in general, communication between all users is possible and is not limited to nearby locations in the physical world. This leads to the core attribute synchronicity being on ML 4.

As outlined in the previous paragraph, the number of users per island is limited. The maximum is 100 users per island [17]. As can be seen from Table 3, the corresponding maturity level for scalability is 2.

At the time of this study, Decentraland can be accessed via a web and a desktop client only [18]. VR headsets are not supported natively, nor other user interfaces. There is an in-world currency, MANA which can be used to trade assets or land in the virtual world, for example. As MANA can also be exchanged into fiat currencies, e. g. US dollar, it has an impact on the physical world, too [19]. This leads the core attribute physical and digital coexistence to be evaluated to ML 2.

As explained in Section 2.E to reach ML 2 regarding interoperability a virtual world would need to have interfaces to make at least one component, e. g. avatars, assets, or wearables, transferable to other

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virtual worlds. As this is not the case with Decentraland, its interoperability ML is 1.

User-generated content plays a vital role in Decentraland. Users can create scenes or experiences on land they own. They can create assets and wearables, and organize events like parties or concerts. All user-generated content can be monetized. Wearables, assets, or land can be traded, and event tickets can be sold [15]. Users can even participate in the DAO controlling the VW and thus influence important decisions regarding Decentraland. Therefore, the attribute user- generated content is on maturity level 4.

As explained in the previous paragraph, UGC can be monetized. Decentraland features its own marketplace [19], but assets are being traded on other marketplaces like OpenSea, too [20]. The example of land clearly shows the relationship between supply and demand. As land in Decentraland is limited, the prices are high [21]. Furthermore, users and their avatars can get hired for jobs and earn money [22]. Maturity level for the core attribute economy is evaluated to 4.

The last remaining core attribute to assess is immersive realism. As can be seen from Figure 1, the visualization of Decentraland is rather in a comic style than realistic. Due to the user-generated content, the environment is rich and appealing. On the other hand, interactions with other users are limited. Users report that most places in Decentraland are relatively empty; avatars gather at very few popular places [23]. And gestures and emotes of the avatars are very limited, too [15]. Users can talk to each other via voice chat. In total, the feeling of immersion is limited, which leads to a maturity level of 2.

Fig. 1: Decentraland Screenshot (Own Picture)

Table III: Metaverse Core Attributes and Corresponding Maturity Levels

	Maturity Levels				
Core Attribute	**1**	**2**	**3**	**4**	**5**
Persistence	turn-based; no persistence; resets are normal	persistent online-platform; not turn-based; continuously online and accessible; planned resets, respawns and updates occur sometimes	persistent virtual world, continuously online; entering or leaving has no impact on the world; no resets; partly not persistent	Large parts of the virtual world are fully persistent; some exceptions exist	Fully persistent virtual world - no exceptions
Synchronicity	Not an online world; no real-time interaction	Live interaction with a limited number of users in a limited space (e. g. lobby)	Live interaction with all users in the virtual world, but limited to regions of the physical world	Live interaction with all users in the virtual world; worldwide; sometimes exceptions with increasing latency or pausing	Whole virtual world is accessible in real time; live communication and interaction; worldwide
Scalability	Up to 10 users simultaneously	Up to 250 users simultaneously	Up to 1000 users simultaneously	Up to 10,000 users simultaneously	No limit
Physical and digital coexistence	No connection to the physical world, except for screen and controller-based means to control an avatar.	One interface, e. g. VR or virtual currency tradable for fiat money	Additional interfaces, several interfaces	Generic changes in the physical world influences virtual world and vice versa	physical and virtual worlds are continuously interfacing
Interoperability	No interoperability; prohibitive	One component, e. g. avatar or asset transferable	Several components transferable	Interoperability with several other virtual worlds	Interoperability with all other virtual worlds

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User-generated content (UGC)	No UGC is possible. UGC is not in vendors focus.	Users have very limited possibilities to change the virtual world. UGC is not in vendors´ focus.	UGC plays an important role. Users can create worlds or spaces, assets, etc.	UGC is possible in a large variety and complexity; UGC can be monetized	Virtual world depends heavily on UGC. The world has to be created by users building on a given base environment. Everything can be monetized.
Economy	No economy; in-app purchases available	virtual economy with virtual currency; fiat money can be exchanged for virtual currency	virtual economy; free self-regulating market (supply and demand); fiat money purchases	virtual economy; free self-regulating market (supply and demand); virtual jobs and services can generate physical world income	Fully developed economy; self-regulating markets; virtual economy blending with physical world economy
Immersive realism	Hardly any feeling of immersion; text chats; avatars without facial expressions	Little immersive experience; avatars provide feeling of individual presence; user can act freely; voice chat	Individual avatars with facial expressions and gesture; voice chat; VR; 3D audio; motion tracking; individual social presence for all users	Including haptic feedback; high-end VR	High level of realism perfectly serving all human senses; creates an immediate immersive experience; hardly distinguishable from the physical world

b) Complete Evaluation Result

Combining the assessment results from the previous Section 5.A leads to the overall picture presented in Figure 2.

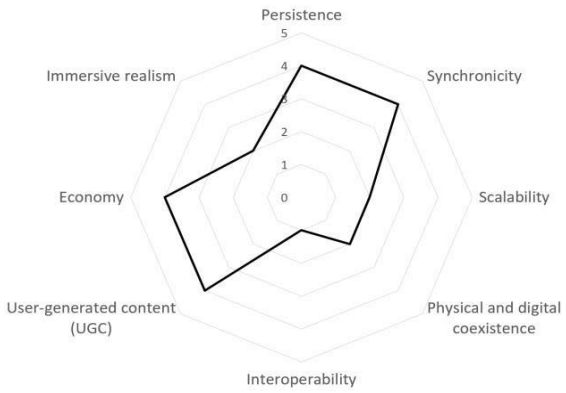

Fig. 2: Complete Decentraland Maturity Assessment Result (Own Picture)

The maturity assessment results show a heterogeneous picture. Half of the core attributes are rated on a high maturity level of 4, i. e. persistence, synchronicity, user-generated content, and economy. As Section 5.A explains the rating in these core attributes depends largely on architectural decisions by the developer team and strategic choices by the governing organization. Immersive realism reached a ML of 2. It depends to some extent on strategic decisions, too, e. g. when it comes to attracting users to participate in the world and to populate it. On the other hand, this attribute also depends on technical development and advancement. This is true for such aspects of avatar interactions as emotes, gestures, and facial expressions. In contrast, the ability of a virtual world to reach high maturity levels in scalability and physical and digital coexistence depends mainly on generic technical advancements. These are related to aspects such as available computing power and connectivity bandwidth for attribute scalability. Physical and digital coexistence primarily relates to the availability of affordable user interface hardware for average users. Interoperability, finally, does not only depend on the virtual world itself but also on technological advancement in terms of standards and the strategic decision of other virtual worlds to apply these standards. Concerning this attribute, Decentraland stays on maturity level 1. There would have been possibilities to reach level 2, for example, by enabling the use of ready player me avatars [24] in Decentraland.

In the previous paragraph, it was pointed out that Decentraland reaches high maturity ratings in core attributes that depend mainly on strategic decisions by the governing entity rather than technology. This implies that Decentralands' strategy is to implement a virtual world in line with the Metaverse vision.

VI. Discussion

Demand for a maturity model for virtual worlds constituting the Metaverse has various reasons. Assessments of existing virtual worlds can indicate important fields for research and development in general. At the same time, assessing an individual VW might provide improvement proposals, which could add to the development roadmap or even the future strategy of the respective VW. And to add another example, maturity assessment results could be an important input for investment decisions. They could answer the question of whether a specific technology is more or

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less relevant to foster Metaverse development, or provide an indication of whether a specific virtual world has promising technology and strategy, which could make it an attractive spot to invest time and money.

The proposed Metaverse maturity model is based on today´s understanding of the Metaverse vision. While it might be helpful to guide decisions in the early stages, already, it will most probably require adaptations in the future. For some applications, e. g. for a company to decide whether investing in virtual real estate is promising, the presented maturity model might not be enough to make an informed decision. Additional data such as the number of active users, acquired funding, which enables further development, or strategic statements of the governing entities can be important, too.

Future research should evaluate and validate the proposed model. As already stated, the model should be adapted according to a future understanding of the Metaverse. In addition, indeed, the presented maturity model should be applied. It can be used to evaluate and compare various virtual worlds at a certain time. Moreover, it can make the development of specific virtual worlds visible and better understandable.

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A Review on the Significance of Implementing Blended Learning in Tertiary Institutions in Ebonyi State-Nigeria

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Abstract- Blended learning can also be referred as E-learning, visual learning, distance learning, embedded learning or mobile learning. It has been popular since the 1980s, Pegler, C & Littlejohn (2007).

E-learning has tremendous potential and promises for education. It allows people to seamlessly share information and learn widely and collaboratively. Blended learning is the integration of traditional face-to-face learning with technology, the internet, and distance learning. This approach is becoming pervasive in the education system in recent years. Blended learning is an effective way of teaching that is flexible and easy to access. Moreover, it can increase students' motivation and their achievement, Kern & Rubin (2012). The usage of technology in teaching and learning is an undeniable need. The effective usage of technology in learning approaches will produce interesting and meaningful learning environments. Studies have revealed that using technology in the process of learning would increase interest, motivation, improve attention span and produce positive mindset towards learning (Bitner & Bitner, 2002; Nguyen, 2015).This research work examines and review the significance of implementing blended learning in teaching and learning in Tertiary institution in Ebonyi State, Nigeria. The objective of the article is to highlight the benefits associated with using blended learning as a viable tool of teaching and learning delivery in tertiary institutions of Ebonyi State.

Keywords: blended learning, online learning, internet, tertiary institutions, E-learning.

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I. Introduction

Blended learning incorporates direct instruction, indirect instruction, collaborative teaching, individualized computer assisted learning, Lalima1 (2017). Information and communication technologies, which have been developing rapidly, have become one of the indispensable elements of the 21st century. They have influenced, like all other fields, educational institutions, which are the most important sub-institutions of the social structure. They have offered a favorable environment for the development and use of various methods and tools. A noteworthy progress has been achieved since the first introduction of information and communication technologies into education. The type of education offered through electrical tools such as video, cassettes and television was called "distance education". Distance education covers many different types of teaching and methods. It can be seen as an umbrella concept covering correspondence courses, televised teaching, radio-broadcast teaching, open learning, computer assisted instruction, telematics, individualized learning and self-learning, Sauve (1993:102).

Distance learning is defined by Greenberg (1998) as a planned teaching/learning experience that uses a wide spectrum of technologies to reach learners at a distance and is designed to encourage learner interaction and certification of learning, Teaster & Blieszner (1999). The term distance learning has been applied to many instructional methods: however, its primary distinction is that the teacher and the learner are separate in space and possibly time". Keegan (1995). Distance education and training result from the technological separation of teacher and learner which frees the student from the necessity of traveling to "a fixed place, at a fixed time, to meet a fixed person, in order to be trained", Keegan (1995). In other words, from these definitions we can see that, distance education is defined as the sort of education in which the distance between learner and educator is emphasized, and technology is used intensively throughout the learning process (Kaya, 2004). Today, with the rapid developments in technology, various tools such as computers, the Internet, cellular phones and satellites have been incorporated into the journey of blended learning, and been taken up in a broader sense. In recent years the spread of computer use, development of Internet technologies and fast Internet connection have paved the way for providing a significant part of blended learning through the Internet. That is why, concepts such as e-learning, online learning or web-based learning, where Internet and network technologies are overwhelmingly used in the presentation and reception of the content, are refer to blended learning.

E-learning is a practical and common method since it presents the learning content in a longer period of time compared with classroom environment and other tools. It ensures the continuation of education twenty-four hours a day, seven days a week. Nevertheless, e-learning environments pose certain disadvantages since they hinder the socialization process of individuals and weaken the attractiveness of traditional e-learning

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environments in the eyes of individuals. This is because instructor and learners most times do not know each other, which results in restrictions in communication.

The above disadvantages triggered search for a new environment, which combines the advantages of e-learning and classical learning environments. This new environment has introduced concepts such as mixed learning, blended learning and hybrid learning. Blended learning can be described as "a learning program where more than one delivery mode is being used with the objective of optimizing the learning outcome and cost of program delivery", (Singh and Reed, 2001).

The term blended learning is also used to describe a solution that combines several different delivery methods, such as collaboration software, Web-based courses, and knowledge management practices. Furthermore Blended learning is used to describe learning that mixes various event-based activities, including face-to-face classrooms, live e-learning, and self-paced learning." (Valiathan, 2002). Another definition of blended learning is the effective integration of various learning techniques, technologies, and delivery modalities to meet specific communication, knowledge sharing, and information needs. (Finn and Bucceri, 2004: 2). In brief, blended learning is a type of education which combines various models of traditional and distance education and makes use of all types of technology. In other words, blended learning has come to be understood as a combination of conventional classroom instruction and e- learning. Blended Learning processes are thus articulated by combining online learning and traditional approaches in various degrees. Blended learning environment which is regarded as a different type of distance education amalgamates the advantages of distance education with the effective aspects of traditional education, such as face-to-face interaction (Finn and Bucceri, 2004). In contrast to classical learning environment which poses restrictions on place and time, e-learning provides an environment where the learners can study regardless of time and place restrictions according to their learning speed. The factors such as learners' individual differences, personal characteristics and learning styles have significant impacts on the learning environment. For instance, the learners who have difficulty in establishing communication in the classroom environment find it easier to communicate in the electronic environment. As mentioned before, the disadvantages of e-learning deriving from the interruption of socialization process and the weakening attractiveness of e-learning applications in the eyes of learners are combined with relevant disadvantages of face-to-face education environments. It is obvious that the weaknesses and strengths of online environment and the weaknesses and strengths of face-to-face education integrate in blended learning. The integration of an online learning environment and a classroom environment is likely to combine ideally the advantageous aspects of both types of instruction. Online or web-based learning environment provides the flexibility and the efficiency which cannot be assured in a classroom environment whereas a face-to-face education class ensures the social interaction in which the students will need guidance for learning. McCampell (2001) emphasizes that blended e-learning will be a suitable approach for incorporating online applications into an existent course program for the first time, and highlights that some parts of the course content should be transferred to the online environment (forum, e-mail, web environment), without offering the whole courses online. However, it is important to establish the equilibrium between face-to-face education and online environments, in view of the advantages of both methods, during the process of organizing blended learning environments. As Ostguthorpe and Graham (2003) states, factors such as instructional objectives, characteristics of students, the condition of online resources and the experience of trainers play an important role in the establishment of this equilibrium. That is why, it is important, in the process of deciding on blended learning environments, to establish the equilibrium between face-to-face and online environments (determining how often teachers and students will encounter, how often they will meet in the discussion environment, etc.) rather than how to present the course.

II. Basic Requirements of Introducing Blended Learning

Implementing blended teaching is not an easy task. It requires certain fundamental preparations in all the elements of teaching learning process. Such element are teacher, student, content designing, and infrastructure. The following are the basic requirements for implementing a successful blended learning.

1. *Well trained Lecturers:* Learning is student centered but teachers are a very essential factor of blended learning. Lecturers should be well acquainted with the concept of blended learning, fully trained and skilled to blend both tradition and technological teaching approaches. They should be trained to develop content in digital form so that it can be available to students online. They should be well versed with internet terminologies, and as well be conversant with the tools that can be useful for the students while learning online. Lecturers should know how to utilize blogs, you-tube facility, software like Skype, goggle talk, Zoom, google meet and others for video conferencing and social networking sites for educational purposes.
2. *Scientific Attitude*: Only Lecturers with scientific attitude should be involved. It is very important that teachers have scientific attitude. This will result on them having good observation skill, being optimistic

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and as well, have problem solving skills. Scientific attitude will help the lecturers to deal positively with failures that might arise while working on this innovative concept and will help to analyze the conditions objectively.

3. *Lecturers With Wider Outlook and Positive Approach Towards Change*: As it is must for the success of any innovative idea or method , blended learning process also need Lecturers that have a wider outlook and should be flexible, All the Lecturers involved should be ready to accept the changes, be very innovative and dynamic.
4. Online Infrastructure/*Facilities:* Blended learning largely depend on infrastructure/facilities, Universities should not only have good classrooms but should also have a well-furnished compute laboratories with sufficient number of computes, internet connectivity, active subscription of video learning based systems such as zoom etc, good campus Wi-Fi, E-learning system as well as subscription to E-facilities/e-books. These are compulsory factors of introducing/implementing blended learning.
5. *Personal Laptop Computers*: In addition to the universities having fully ICT friendly campuses, students and lecturers should have basic hardware support to learn and teach online and offline at their residence as well. To further implement this, there should be program to sale Laptop computers at affordable price and payment made installment to both lecturers and the students by the school managements or government and non-governmental agencies.
6. *University System/Program Flexibility*: University system should also made to be flexible to accommodate blended learning. Flexible time table, school fees payment, course registrations, and examinations system etc are all very crucial for a seamless blended learning implementation.
7. *Parent/Guidance Support*: The support of parents or guidance is also very pivotal to the successfully implementation or introduction of this innovative approach to and learning.
8. *Provision for Online Assessment/Examination*: The higher education and university authorities should completely make provision for online continuous assessment and examination for successful execution or implementation of blended learning.

III. Importance of Blended Learning

1. *Virtual Classroom*: Blende Learning provides students and lecturers an option to teach or learn anywhere, anytime. Students can be a part of a virtual classroom meeting with his co-students and teacher in cyber space irrespective of the geographical boundaries. With world today being a global village, students through this mode will be at par with his counterpart at any other part of the world and will get multicultural experience as well.
2. *Student Interaction With Course Content*: Traditional mode of teaching and the school campus provides student time to interact directly with their course content through printing material while ICT mediated learning provides them indirect interaction with their course content in a versatile and diverse interesting way. The videos provide required realism to the content and sharing on blogs and visiting e-books provide new and updated perspectives to the content/course materials.
3. *Face to Face Teaching*: Blended learning provides full scope for traditional classroom teaching where students get ample of time to interact with their teachers and thus get influenced by their personality, behavior and value system. Face to face interaction helps in synchronous communication. Teachers and students both are able to get immediate feedback that in turns is favorable for teaching/ learning process. Face to face interaction is highly motivating for both the teachers and students and it gives a human touch to the process.
4. *Peer Group Interaction*: Inside the school campus students learns by formal means and they learn informally when they interact with their peer groups. Many needed life skills and social values are practiced in non-formal interaction with their peer groups. School campus provides many opportunities for this during playground activities and social exchange during free time.
5. *Accessing E-Library:* E-library is a part of ICT supported teaching /learning in blended learning. In traditional mode students, get access to school library that is limited but digital library gives them access to different books related to their topic and on diversified areas. This widens their outlook and enriches their knowledge as well as helps in meeting the cognitive objectives.
6. *Online Assessment*: Immediate feedback is a key factor in learning as it motivates the learner and is based on principles of readiness. Online assessment helps to make evaluation system more formative, transparent and more fast. It becomes more reliable and objective.
7. *E-tuitions*: students have different needs. Few of the students do not get benefits from classroom teaching, as they continuously require personal guidance and complete attention. Such students may choose the option of e-tuition that is meeting a private tutor and getting personal guidance in cyber space via video conferencing.
8. *Accessing and Maintaining Educational Blogs*: Students get less opportunity for nurturing their creativity in traditional classrooms because of rigid

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timetable and lot of pressure of class work, assignments and coping with examination stress but educational blogs provide students a platform to show their creativity and can get feedback also. In addition to it, educational blogs are a good platform to discuss topics of importance that are not the part of syllabus like those related to social problems, political issues, and other issues relevant to youths like drugs addiction, delinquency, population education etc.

9. *Webinars*: Webinar is an also a feature of blended learning that is ICT supported format. It means that students participate in seminars in different topics relevant to them via internet connection. All the participants are connected through different software is available like Skype, Google talk etc. and then present their paper and participate in discussions through video conferencing.
10. *Viewing Expert Lectures in Youtube*: Blended earning provides student to gain advantage of the experts of the course content they are studying as they can easily watch the different lectures by renowned experts from different fields available on you tubes. In addition to it, college can also upload video of lecture by its own teachers so that if student is not able to attend the college he can avail this facility and can gain benefit of the teachers teaching.
11. *Online Learning Through Videos and Audios*: Various recordings, animated videos are available that explain various concepts very easily and in interesting way. They are based on the principle of realism and connecting with life. So students can get feel of real life while studying and it makes the difficult concepts and phenomenon concrete for the students.
12. *Virtual Laboratories*: It can be used in professional courses where the laboratory work is very crucial and sometimes the cost of establishing a well-furnished laboratories is not feasible and in few cases the experiments are dangerous and it is not safe for students to handle those equipments then in such cases students.
13. As part of learning is done through ICT, online or offline mode so teachers and students get more time in the classroom for creative and cooperative exercise.
14. Students gain advantage of online learning and CAI without losing social interaction element and human touch of traditional teaching.
15. *It Provides more Scope for Communication:* Communication cycle is completed in blended learning which is not possible if we follow only traditional approach
16. Students become more techno savvy and they gain enhanced digital fluency
17. Students have more strengthened professionalism as they develop qualities like self-motivation, self-responsibility, discipline
18. It updates course content and so gives new life to established courses.

IV. Challenges of Blended Learning

Blended learning in spite of the advantages that it has when adopted in education, also has some disadvantages. Studies support that e-learning or blended learning possesses some disadvantages (Collins et al. 1997; Klein and Ware, 2003; Hameed et al, 2008; Almosa, 2002; Akkoyuklu and Soylu, 2006; Lewis, 2000; Scott et al. 1999; Marc, 2002; Dowling et al, 2003; Mayes, 2002). For example despite the claims that e-Learning can improve the education quality, Dowling et al. (2003) argue that making learning materials available online results in improved learning results only for specific forms of collective assessment. In addition, Mayes (2002) asked a question of whether e Learning is simply a support device for existing methods of learning. The most noticeable condemnation of e-Learning is the complete absence of vital personal interactions, not only between learners and instructors, but also among colleague learners (Young, 1997; Burdman, 1998).According to Almosa (2002), regardless of all the disadvantages of e-learning, there are a lot of benefits which inspire its use and also encourage the search for ways to reduce disadvantages. The challenges or disadvantages of e-learning/blended learning that have been given by studies include the following:

1. E-learning as a method of education makes the learners undergo contemplation, remoteness, as well as lack of interaction or relation. It therefore requires a very strong inspiration as well as skills with to the management of time in order to reduce such effects.
2. With respect to clarifications, offer of explanations, as well as interpretations, the e-learning method might be less effective that the traditional method of learning. The learning process is much easier with the use of the face to face encounter with the instructors or teachers.
3. When it comes to improvement in communication skills of learners, e-learning as a method might have a negative effect. The learners. Though might have an excellent knowledge in academics, they may not possess the needed skills to deliver their acquired knowledge to others.
4. Since tests for assessments in e-learning are possibly done with the use of proxy, it will be difficult, if not impossible to control or regulate bad activities like cheating.
5. E-learning may also probably be misled to piracy and plagiarism, predisposed by inadequate

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selection skills, as well as the ease of copy and paste.

6. E-learning may also deteriorate institutions' role socialization role and also the role of instructors as the directors of the process of education.
7. Also not all fields or discipline can employ the e-learning technique in education. For instance the purely scientific fields that include practical cannot be properly studies through e-learning. Researches have argued that e-learning is more appropriate in social science and humanities than the fields such as medical science and pharmacy, where there is the need to develop practical skills.
8. E-learning may also lead to congestion or heavy use of some websites. This may bring about unanticipated costs both in time and money disadvantages (Collins et al. 1997; Klein and Ware, 2003; Hameed et al, 2008; Almosa, 2002; Akkoyuklu & Soylu, 2006; Lewis, 2000; Scott et al. 1999; Marc, 2002)

V. Conclusion

According to Dr. Ranjana Bhatia, advantages of blended learning are: Greater efficiencies with group sizes, Support professional/work-based skills development, Flexible study, with learning on-demand, anytime or anywhere, to meet learners 'needs wherever they want, Wide access to digital resources, shared tools, and information systems. And according to Graham (2006), three main reasons why the blended learning is recommended are: Boosting up the effectiveness of education, Increased access and convenience, Greater cost-effectiveness, Easy to access resources, Live feedback in the classroom, Flexible lessons, No need to large buildings. Altogether, these findings show the significance of blended learning in teaching, for it is the bridge of promoting students' knowledge breadth and depth. In a technologically developed era, using only in person instruction is fruitless for electronic loved students. Alternatively, adopting solo online learning has its demerits such as late feedback, difficulty with the engagement of students, social isolation, and lack of motivation. One last word must be said that, by designing a blended course effectively and integrating positive sides of online and face-to face education, ones can reach mastery of the content. Adopting technology in the education system and blended learning is valuable in the academic world therefore; it can be further studied and made new concepts.

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Plagiarized content will not be considered for publication. We reserve the right to inform authors' institutions about plagiarism detected either before or after publication. If plagiarism is identified, we will follow COPE guidelines:

Authors are solely responsible for all the plagiarism that is found. The author must not fabricate, falsify or plagiarize existing research data. The following, if copied, will be considered plagiarism:

- Words (language)
- Ideas
- Findings
- Writings
- Diagrams
- Graphs
- Illustrations
- Lectures

- Printed material
- Graphic representations
- Computer programs
- Electronic material
- Any other original work

Authorship Policies

Global Journals follows the definition of authorship set up by the Open Association of Research Society, USA. According to its guidelines, authorship criteria must be based on:

1. Substantial contributions to the conception and acquisition of data, analysis, and interpretation of findings.
2. Drafting the paper and revising it critically regarding important academic content.
3. Final approval of the version of the paper to be published.

Changes in Authorship

The corresponding author should mention the name and complete details of all co-authors during submission and in manuscript. We support addition, rearrangement, manipulation, and deletions in authors list till the early view publication of the journal. We expect that corresponding author will notify all co-authors of submission. We follow COPE guidelines for changes in authorship.

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Appealing Decisions

Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

Declaration of funding sources

Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for writing a good quality Computer Science Research Paper

Techniques for writing a good quality computer science research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of computer science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

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6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10.Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

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Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

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Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals Inc. (US).

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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