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Feature Point selection for facial paralysis, Classification of severity with neural network

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Abstract:-

Paralysis is a disease that affects the voluntary movements of muscles in the human body. Facial paralysis is a disease that affects the movements of muscles in the face on one side or both sides. Cranial nerves are responsible for various movements in the face and they originate from the brain and brain stem. Any damage in this cranial nerve system results in the loss of voluntary facial movements. The symptoms of facial paralysis are defacement of face during rest and certain expressions like drooping of eye, drooping of mouth corner, etc., during normal action. The patient affected by facial paralysis experiences difficulties in carrying out daily activities such as eating, drinking, and communicating and loss of taste and loss of hearing. It is necessary to assess the current level of severity of facial paralysis that has been acquired by the patient in order to treat the patient according to the severity of the disease. An accurate method for evaluating the disease will be an indispensable tool for the physician to choose appropriate treatment. The proposed research work focuses on assessment of the severity of facial paralysis. An accurate and quantitative evaluation of degree of facial paralysis is presented. This method evaluates the degree of facial paralysis on one side of face and classifies the severity of facial paralysis. The salient points are

marked on both the sides of facial features in different facial expressions, and computation of overall degree evaluation values is carried out by an algorithm called Feature Point Selection Algorithm (FPSA). This algorithm comprises a sequence of the following steps: computation of distance between salient points on facial feature separately for left side and right side during each expression, selection of maximum and minimum distance from left and right side during each expression, computation of the difference between maximum distance of healthy side and sick side, also the difference between minimum distance of healthy side and sick side. The average of all difference of maximum distance and average of all difference of minimum distance are the overall degree evaluation values for a patient.

Digital applications have occupied every sphere of modern life. In the health care field, an array of sophisticated efficient equipments has been in vogue. Precise diagnosis of a disease is made easy with the help of analysisthrough computers. This thesis presents a computer software to diagnoseprecisely the stage of facial paralysis so as to facilitate appropriate treatment. It is a decision-making tool.

Paralysis is the inability of one or more muscles in the human body to do voluntary movements. It may be also associated with loss of sensation and other bodily functions. Muscle in itself is not responsible for paralysis. Paralysis is most often caused by damage to the nervous system or brain, especially the spinal cord while muscles may stay intact with themselves. X-rays, MRI scan, CT scan, myelography, electromyography are the tests used to diagnose the paralysis.

Causes of Paralysis

Paralysis is caused by many reasons. The most common causes for paralysis are stroke, head injury, spinal cord injury and multiple sclerosis. Besides these causes, cancer, cerebral palsy, Friedreich's ataxia, Guillian- Barre syndrome, Lyme disease and spina bifida can also give rise to paralysis

Stroke

For its proper function, the brain needs constant supply of blood that contains oxygen and nutrients. Stroke will occur when the blood supply to the brain is interrupted or stopped. If blood supply to the brain is disturbed or restricted, the brain cells will begin to die which leads to brain damage resulting paralysis.

Head injury

A severe head injury can impair the brain. If brain hits the skull, brain surface can tear or bruise, and blood vessels and nerves may get damaged. During a severe head injury, if a part of the brain gets damaged that controls the specific muscles it may result in paralysis. Damage to the right side of the brain will cause paralysis to left side of the body and any damageto left side of the brain will cause paralysis to the right side of the body.

Spinal cord injury

Spinal cord is the element of central nervous system. It is a bunch of nerves that starts from brain, runs down through neck and spine, inside a canal of vertebrae. The main function of spinal cord is to transmit signals between brain and body. If either neck or spine gets damaged, spinal cord willalso get damaged. This damage may result in paralysis as brain may not be able to transmit signals to the muscles.

The exact location where the spinal injury occurs can have a significant effect on how severe and wide-ranging the paralysis is. The higher up the spine the injury occurs, the worse the paralysis will be. An injury in themiddle of spine will cause paralysis in the lower limbs. A neck injury will

cause paralysis in all four limbs and loss of normal lung function in whichperson will require ventilator to breathe.

Multiple Sclerosis

Multiple Sclerosis is a state when nerve fibres in the spinal cord aredamaged by the immune system. Nerve fibres are surrounded by substance called myelin and this substance facilitates the transmission of nerve signals. Signals from and to the brain will be hampered if immune system attacks the myelin. This may result in paralysis (Kanerva & Pitkaranta 2006).

There are also less common causes for paralysis. These are listed below.

Cancer

Cancer that develops in the brain like a high grade brain tumour cancause paralysis on one side of the body. As well as, cancer that extends from others parts of the body to brain or spinal cord will also lead to paralysis.

Cerebral palsy

Cerebral palsy is a condition that affects a child's movement and coordination. Cerebral palsy caused by brain damage which occurs before, during or soon after birth. Infections during early pregnancy, a difficult or premature birth, bleeding in the baby's brain, abnormal brain development in the baby are some causes of cerebral palsy.

Friedreich's ataxia

Friedreich ataxia is caused by a mutation in a gene known as the Glucosidase Alpha Acid (GAA) gene. It results in gradual increase of paralysis in the legs.

Guillian–Barre syndrome

In Guillian-Barre syndrome, the body's immune system attacks the nerves of the peripheral nervous system, which causes them to become inflamed. This damage to nerves results in a tingly, numb sensation in the arms and legs, which may lead to temporary paralysis of the arms, legs and face.

Lyme disease

Lyme disease is a bacterial infection caused by infected ticks that may spread to people. Ticks are small insects that feed on the blood ofmammals including humans. They release bacteria that will damage the nerves, leading to temporary paralysis of the face.

Spina bifida

Spina bifida is termed as a series of defects that affects development of the spinal cord and brain. It causes damage to the nervous system which results in partial or permanent paralysis of lower limbs.

Symptoms of Paralysis

A symptom of paralysis generally includes loss of movement of muscles. Paralysis has significant effects on the other systems of body also. These include

- changes in circulation and respiration
- changes in kidneys and gastro intenstinal system

- changes in muscles, joints and bones
- spasticity of the limbs
- muscle spasms
- pressure sores
- blood clots in the lower limbs
- feelings of numbness and sensations
- skin injury
- bacterial infection
- disruption of normal working of tissues, glands and organs
- constipation
- loss of control of urination
- sexual difficulties
- vision problems
- difficulty in thinking, speaking or swallowing
- behavioral issues

Classification of Paralysis

Paralysis can be classified in different ways, as below:

- localized or generalized
- temporary or permanent
- partial or complete
- spastic or flaccid

Localized or generalized

In localized paralysis a specific section of the body is affected. Examples of localized paralysis are facial paralysis, paralysis of the hand, and paralysis of the vocal cord.

In generalized paralysis a larger area of the body is affected. Examples of generalized paralysis are monoplegia (only one arm or one leg paralyzed), paraplegia (lower half of the body including both legs becomes paralyzed), quadriplegia (both hands and legs are paralyzed), and hemiplegia (one side of the face, arm and leg are paralyzed).

Temporary or permanent

Paralysis caused by Bell's palsy is the cause for temporary paralysis. Sometimes, paralysis after a stroke is also said to be temporary paralysis.

Paralysis caused by serious injury is generally a permanent paralysis. Broken neck is an example for permanent paralysis.

Partial or complete

Paralysis can be partial paralysis when there remain some muscle function and sensation. For example, a person affected by partial paralysis canmove one leg or one arm but not the other, or feel sensation of heat and cold.

Paralysis can be complete paralysis when there is complete loss of musclefunction and sensation.

Spastic or flaccid

Paralysis can be spastic where muscles of affected limbs are abnormally stiff or exhibit spasms and movements that are not managed by anindividual.

If muscles in affected limbs are droopy and weak, then it is flaccid paralysis. Muscles in the flaccid paralysis may shrink.

NERVOUS SYSTEM

The nervous system coordinates all the activities in human body. This system permits us to perceive, realize and respond to the environment around us. The main functions of nervous system are sensory function, interpretative function and motor function. The Nervous system consists of Central Nervous System (CNS) and Peripheral Nervous System (PNS). The CNS is the primary control centre for the body and it includes brain and spinalcord. The PNS connects the CNS to the rest of the body through nerves like cranial nerves and spinal nerves. The sensory nerve accumulates the information from the environment and carries to CNS. In the CNS, the accumulated information is interpreted. The interpreted information is communicated to muscles and glands of the body.

Central Nervous System

The CNS includes the brain and spinal cord. The brain is the collection of soft nerve tissues which is encapsulated in the skull. It is the destination for the information collected from the sensory unit. Once theinformation reaches the brain, it will sort and record before giving the necessary commands to the peripheral nerves (Rajini & Bhavani 2011).

Brain

The brain is divided into cerebrum, cerebellum and medulla.

Cerebrum is the largest part of the brain. It is the centre for all the thoughts and intellectual activities. The left side of the brain controls the right side parts of the body. The right side of the brain controls the left side parts ofthe body.

Cerebellum resides below the cerebrum at the rear of the skull. It receives the information from sensory units, the spinal cord and brain, and then stimulates the motor units. It is responsible for all voluntary movement of muscles.

Medulla is responsible for controlling the heart beat, breathing,swallowing and coughing. Along with pons and mid brain, the medulla forms the brain stem that connects the brain with spinal cord.

Spinal cord

Spinal cord is a long and cylindrical tissue. It is a collection of nerve tissues extending from the medulla down to the second lumbar vertebrae. It acts as message lane between the brain and the remaining parts ofthe body.

Peripheral Nervous System

The PNS is distinguished into autonomic system and somatic system. The autonomic system includes the organs that perform involuntary actions of the body. The somatic system includes the parts of the body that can perform voluntarily. The somatic system includes the following nerves

- spinal nerves
- cranial nerves

Spinal nerves

The nerves that emerge from the spinal cord are called spinal nerves. There are 31 pairs of spinal nerves and those nerves are named based on their location on the spinal cord (Chunbao Wang et al 2012). Each spinal nerve will have both dorsal root and ventral root. Each dorsal root has sensory

fibres from the skin, subcutaneous and deep tissues. Each ventral root has motor fibres that stimulate or activate the muscles and glands. These nerves carry the impulse between the brain and the spinal cord and also to other partsof the body (Kunhimangalam et al 2013). The impulses are carried to other parts of the body either directly through these nerves or through secondary nerves called plexus. Four different spinal nerve plexus are there in the humanbody, namely cervical plexus, brachial plexus, lumber plexus and sacral plexus.

Cranial nerves

The nerves that originate from the brain and brain stem are called cranial nerves. There are 12 pairs of cranial nerves and these nerves are associated with neck and head (Kanerva & Pitkaranta 2006). Cranial nerves carry the sensory and motor information between the brain and other regions of the body especially the neck and the brain. Each cranial nerve is paired andpresent on either side of the neck and the head. The cranial nerves are designated with number and name where the name is related with its function.The cranial nerves are as follows:

i) Olfactory nerve
ii) Optic nerve
iii) Oculomotor nerve
iv) Trochlear nerve
v) Trigeminal nerve
vi) Abducens nerve
vii) Facial nerve
viii) Vesiblocochlear nerve
ix) Glossopharyngeal nerve
x) Vagus nerve
xi) Accessory nerve
xii) Hypoglossal nerve

The olfactory nerve, optic nerve and vesiblocochlear are the sensory nerves. The oculomotor nerve, trocholear nerve, abducents nerve, accessory nerve and hypoglossal nerve are the motor nerves. The remaining nerves are mixed nerves. Figure 1.1 shows the disposition of cranial nerves.

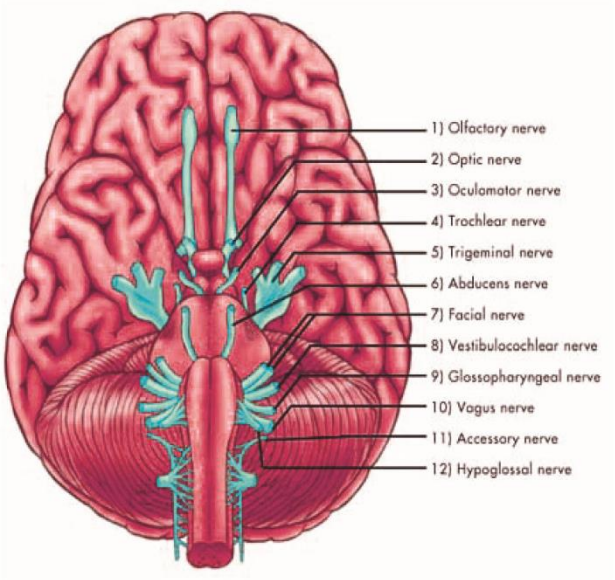

Figure 1.1 Cranial nerves

Olfactory nerve

This is the first nerve of the cranial nerve system and it transmits the smell to the brain. Any damage to this nerve results in anosmia (inability to smell) and parosmia (a distortion in sense of smell). The worst case can cause in lack of sensing the taste.

Optic nerve

The optic nerve conveys the visual information to the brain. Injuriesto the optic nerve will result in visual disorder and even blindness (Chunbaoet al 2009).

Oculomotor nerve

The oculomotor nerve is the third nerve. The functions of oculomotor nerve are to transmit the signals to eyeballs to move in all directions that cannot be controlled by cranial IV and V nerves, and to adjust the pupils and the lens of eyes. Any injury to oculomotor nerve causes in diplopia (double vision) and blown pupil (the pupil that cannot tighten).

Trochlear nerve

The Trochlear nerve controls the muscle that moves the eye balls down and out. The hurt to trochlear nerve will results in diplopia and inability to move the eyeballs downwards and outwards.

Trigeminal nerve

The trigeminal nerve is a mixed nerve and it is the largest nerve. This nerve conveys the sensations of face to the brain. It also controls the facial muscles that are associated with chewing. Injury to this nerve leads to trigeminal neuralgia (severe face pain) and cluster headache.

Abducens nerve

The abducens nerve coordinates the eyeball movement towards out. Damage to this nerve results in diplopia.

Facial nerve

The facial nerve is the seventh nerve of the cranial nerve system and main function of this nerve is to move the muscles in the face. This nerve is also responsible for secretion of saliva, tears, taste and sensation around ears. Facial nerve emerges from the lower part of pons at the base of the brain stem and consecutively gets connected with cerebellum, menings, internal auditory canal, internal nerve, inner ear, middle ear, mastoid and parotidgland (Carien et al 2003). The nerves exit parotid gland and divides into five main branches of facial nerve and reaches the facial muscles. Each branch is responsible for moving a part of the face. The five main branches are temporal, zygomatic, buccal, cervical and marginal mandibular. Figure 1.2 shows the facial nerve and its branches.

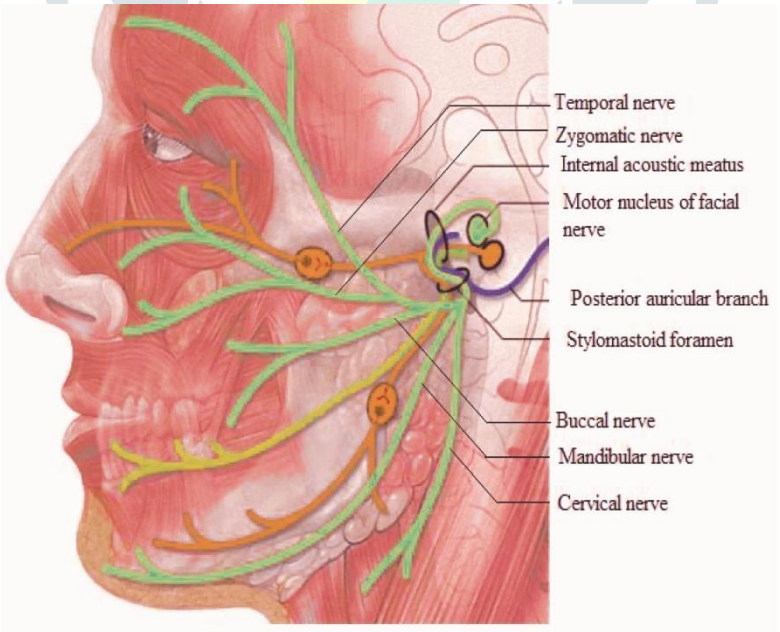

Figure 1.2 Facial nerve and its branches

Temporal nerve traverses through muscles of temples, sides offorehead, eyebrows, eyelids, and upper part of the cheek (Chan et al 2009). The zygomatic nerve is associated with movement of upper chin and upper

lip. Buccal nerve is responsible for the movement of the mouth. Mandibular nerve is associated with lower chin and lower lip. The cervical nerve runs both sides of the neck.

Disorders in facial nerve will lead to facial palsy or facial paralysis.A patient with facial paralysis will have disfigurement of face at rest and at posture, drooped eyes, drooped lips and difficulties in swallowing of food, conversing and smiling (Benecke 2002).

Vestibloucochlear nerve

The vestibluocochlear nerve is the eighth nerve of the cranial nerve system and it is composed of two nerves namely, vestibular nerve and cochlear nerve. This nerve is responsible for posture, movement, balance and hearing. Damage to this nerve causes vertigo (giddiness), nystagmus (unmanageable oscillations of the eyes) and deafness.

Glossopharyngeal nerve

The glossopharyngeal nerve is a mixed nerve, which joints thesensory nerves to the tonsils, tongue and small portion of ear, and connects the motor nerves to stylopharyngeus and parotid gland. This nerve conveys the information about taste, sensation, salivation and swallowing. Injury to this nerve leads to stylopharyngus neuralgia (painful while swallowing).

Vagus nerve

The vagus nerve is also a mixed nerve and is similar to glossopharyngeal nerve. It nerve is also responsible for speech, cough, swallowing, secretion of saliva, sensations, maintaining the blood pressure and the levels of the oxygen and carbondioxide in blood. Damage to this nerve results in difficulty in swallowing and vocal defects.

Accessory nerve

The accessory nerve is the nerve that arises from spinal roots and cranial roots. This nerve is responsible for swallowing, movement of neck, head and shoulder. Malfunction of this nerve will lead to inability to move theshoulders and droop of the shoulder.

Hypoglossal nerve

The hypoglossal nerve is the twelfth nerve and connects the muscles to the tongue. Damage of this nerve will cause fasciculations, atropy and the tongue will stick out towards the damaged side.

FACIAL PARALYSIS

Facial paralysis can be on one or both sides of the face. Thisdisease is caused by the impairment of facial nerve. Facial nerve is a mixed nerve as it consists of both motor and sensory part (Herbert 1998). The motor part joints the somatic motor fibres to the muscles of face, scalp and auricle. The sensory part contains the fibres of taste in the anterior two thirds of the tongue and oral cavity. The facial nerve also carries parasympathetic fibres to the salivary and lacrimal glands (William et al 1997).

The motor nerves of facial nerve emerge from brainstem and connect with the facial muscles. This nerve enters into canal called Internal Auditory Canal (IAC), which is composed of bones in the temporal lobe ofthe skull. The nerves exit from IAC, turns and enters into middle ear space and once again turns and enters into mastoid bone of the skull. The nerve passes through the mastoid gland and leaves the skull in front of ear where it divides into several branches. It is entrenched with parotid gland (salivary glands) in frontage of the ear (Kanerva & Pitkaranta 2006).

Figure 1.3 shows the image of a paralyzed face. Damages in the facial nerve between brain stem and parotid gland will lead to weakness of all branches of facial nerve. The lower face below the eyes will become weak if there is any damage to facial nerve in the brain (Shu He et al 2007).

Figure 1.3 Paralyzed Face

Symptoms of Facial Paralysis

The symptoms of paralysis have already been discussed already in

Albeit, the symptoms of the facial paralysis are presented below foreasy reference (Terence & Haynes 1956)

- Disfigurement of the face at the rest and at posed expressions
- Functional difficulties in activities of daily living such as eating,drinking and communicating
- Drooping at the corner of the mouth
- Drooping of the eye brow
- Wrinkles of the eye brow
- Abnormal secretion of tears
- Hearing impairment
- Scab and blister around the ear
- Loss of taste in the anterior two third of the tongue
- Numbness in the limbs

Causes of Facial Paralysis

- Damage or swelling of facial nerve or area of the brain thatsends signals to facial muscles (Elisabet et al 2006).
- Melkersson–Rosenthal syndrome (swelling of face and lips, anddevelopment of folds and furrows in the tongue).
- Head or neck tumour
- Trauma
- Chronic middle ear infection or other ear damage
- High blood pressure
- Diabetes
- Lyme diseases (bacterial diseases transmitted to the humanbody by tick bite)
- Ramsay-Hunt syndrome (a viral infection of the facial nerve)
- Guillain-Barre syndrome (which affects nervous system)
- Neoplasms (abnormal growth of tissue)
- Neurosarcoidosis (inflammation of various tissues constitutingthe brain and

the spinal cord)

- Multiple sclerosis (auto-immune diseases)
- Familial, metabolic and toxic reason

Types of Facial Paralysis

Facial paralysis can be distinguished as

- Central facial paralysis, and
- Peripheral facial paralysis

Central Facial Paralysis

Central Facial Paralysis is a paralysis that affects lower facial muscles but the forehead and eyes are spared. Figure 1.4 shows the central facial paralysis (Kanerva & Pitkaranta 2006).

Figure 1.4 Central facial paralysis

Peripheral Facial Paralysis

Peripheral Facial Paralysis is paralysis that affects the voluntaryand involuntary movements of all facial muscles (Kunhimagalam et al 2013). Figure 1.5 shows peripheral facial paralysis where lower facial muscles, forehead and eyes are affected.

Figure 1.5 Peripheral facial paralysis

FACIAL GRADING SYSTEMS

Facial paralysis is a devastating disease. Though it can occur onone side or both sides of the face, and it occurs mostly on one side of the face.Before starting the treatment, the physicians have to estimate the severity of facial paralysis. An accurate and reliable facial grading system is required for estimating the status of facial paralysis. Two different approaches are used in estimating the degree of facial paralysis (Ho Yun et al 2013). They are

- Traditional approaches
- Computer based approaches

Traditional Approaches

In traditional approaches, physicians use subjective assessment for evaluation of facial paralysis. This approach includes marking points on the face and dysfunction of facial nerve is assessed by measuring the distance between points on facial features and level of disease is estimated (Gunaratne & Sato (2003). This is a time consuming process. House classified the traditional grading system as

- Gross,
- Regional, and
- Specific

Gross scale

The gross grading system assesses overall facial motor function andprovides the grade for severity of dysfunction of facial nerve. Botman and Jongkees scale, May scale, Pietersen scale and House-Brackmann scale are examples of the gross scale of facial function (House 1983).

Regional Scale

In regional category, the assessment is made in terms of score for different areas of facial function separately (Shu He et al 2008) and (Lian Liu et al 2010). Finally the composite score gives the level of facial paralysis. Theexamples of regional grading systems are Smith scale, Yanagihara grading system, Sunnybrook facial grading system, Detailed Evaluation of Facial Symmetry (DEFS), Janssen's scale, and Adour and Swanson Scale Facial Paralysis Recovery Profile (FPRP) (Shaoyu wang & Feihi Qi 2005).

Specific Scale

Specific category grading system assesses the questions put to the patient and the responses from the patient (Elisabet et al 2006). Stennert- Limberg-Frentrup scale, Burres-Fisch system, and Nottingham system are examples of specific category-based grading systems.

Computer based Approaches

The computer-based approach will assess the facial paralysis objectively by using specialized equipment and image processing techniques.

Several computer-based methods have been proposed with objective and quantitative assessment of facial paralysis (Shaoyu & Feihu 2005). Maximum Static Response Assay (MSRA), Automated Face Image Analysis (AFIA) and Glasgow Facial Palsy Scale are examples for computer-based facial grading system (Wan Syahirah & Kenneth 2013). MSRA evaluates bilateral facial paralysis using regional and specific facial scale. In MSRA, assessment is carried out by comparing the amplitude of facial movement at different facial expressions and at rest (Johnson et al 1994). AFIA evaluates the facial paralysis based on the lip movement. This system automatically detects, and extracts facial features and evaluates the status of facial paralysis.

MOTIVATION

Evaluation of facial paralysis is essential that facilitates the physician to treat the patient with current condition of the disease. In the existing method, the physician assesses the disease by placing the salient points on the face and measures the distance manually which is a time consuming process.

There is a possibility of occurring inter-observation and intra- observation error at the time of assessing the disease. Therefore, an approach with high accuracy to evaluate quantitatively the state of facial paralysis will be an invaluable tool for the physician. Hence, a new procedure has been developed in this research work.

OBJECTIVE OF ARTICLE

The objective of the proposed work is to develop an algorithm that evaluates the degree of facial paralysis and classifies the severity of facial paralysis more precisely. In the proposed research work, the objective has been achieved through the following steps:

- Getting images of a patient with four different facial expressionsfrom data base and marking of salient points on the facial features in each expression.

- Distance computation among the salient points in both sides of the face during each facial expression and computation of overall degree evaluation values.

- Assessment of facial paralysis and classification of severity level of disease obtained without any human intervention.

Conclusion:-

Facial nerve palsy is commonly seen and requires prompt evaluation and diagnosis. The majority of cases can be managed with medical treatment alone but ENT or neurology referral should be considered in atypical cases. Despite most patients having a favorable outcome, there is a call for primary care physicians to appreciate the need for accurate diagnosis and the importance of early treatment, particularly if the diagnosis is anything other than Bell's palsy. Further research is required to identify those at risk of permanent paralysis and measures to prevent this.

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