Survey on Model Predictive Control System for Various Applications

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Abstract: **- In process control model predictive control is one of the reliable methods, which with the help of mathematical equation or model forecasts the future behavior of the system. This paper conveys an overview of available model predictive control (MPC) design for various types of devices or processes. By the help of MPC, device or processes uninterrupted services for the longer time is provided. A general Model Predictive Control architecture is depicted and various kind of approaches are taken for MPC design by each author for the different area are described. Our goal is to provide a conceptual review of the results.**

Keywords:-**Model Predictive control (MPC), Field Programmable Gate Array (FPGA), High Level Synthesis tool (HLS tool), Robust Model Predictive Control (RMPC), Direct Matrix Converter (DMC).**

I. INTRODUCTION

Many numbers of the process control methodology are available as Proportional–Integral–Derivative (PID) Control System, Fuzzy Control System, Feedback Control System and Model Predictive Control System etc. Some of these control methods available provide only the error information of the process but Model Predictive Control method provides upcoming error information and tries to remove it, that's why the process run flawlessly.

Initially, it was used only in medical and chemical industries because of their low speed but nowadays because of its performance, it may be applied to high-speed industrial applications. It has a capability to diagnose the problem before its occurrence that's why devices can be works uninterruptedly and provide services for a long time.

In it, the system model is used to store the mathematical model of the device or process. The accuracy of the system depends on the accuracy of the mathematical model. If it deviates from the desired path that means inaccurate modelling has been done and we have to redesign the model again. Optimizer corrects this model mismatching error and protects our system from upcoming process interrupts. The optimizer uses a various parameter to control device according to given mismatching information by system model. These parameters can be a time constraint and can be a cost function and the other physical parameter.

According to specific work various different types of Model Predictive Control system are available like-

(1) Discrete time Model Predictive Control system
(2) Continues time Model Predictive Control system
(3) Multivariable Model Predictive Control system
(4) Constrained Model Predictive Control system
(5) Model Predictive Current Control system
(6) Rate Based Model Predictive Control system
(7) Robust Model Predictive Control system
(8) Nonlinear Model Predictive Control system
(9) Potential Field-Based Model Predictive Control system

II. MODEL PREDICTIVE CONTROL ARCHITECTURE

Basically, Model Predictive Control System Consists of an Optimizer, Cost Function, System Model and Constraints as depicted in Fig 1. Optimizer on the basis of inputs from reference setpoints, cost function and the system model perform the process of controlling.

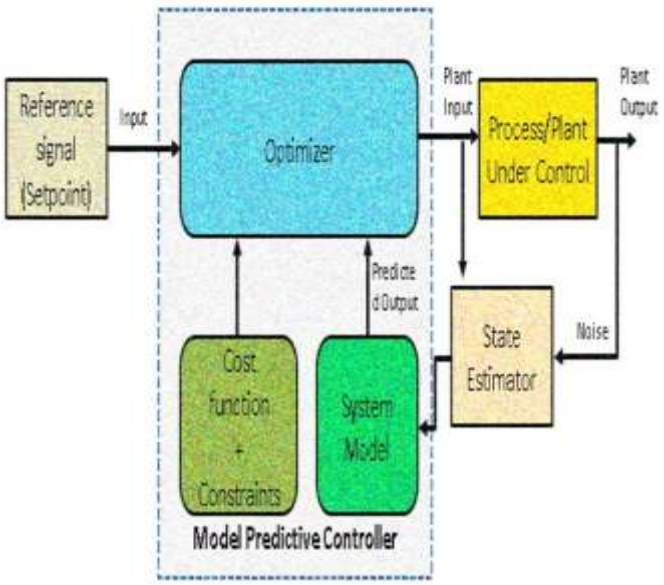

Fig 1: Architecture of Model Predictive Control system

MPC system integrates stochastic control, optimal control, multivariable control, future referencesand process controlaccurately. By the help of MPC Nonlinear Processes can be handled which are frequently occurred in the industry, this is also another advantage of it. Although MPC has been found to be a durable type of control system in most of the reported applications, stability and durability proofs have been tough to obtain reason behind that is the finite horizon used. For a higher efficiency of controlling very accurate modelling is required.

III. LITERATURE REVIEW

In [1] Model Predictive Control for Embedded Systems Using High-Level Synthesis Tool". In this paper authors used Field Programmable Gate Array based controller for Model Predictive Control system design. They follow two steps for obtaining an optimized and simple MPC system.

IstStep: With the help of the μAOMPC tool to generate code with efficient libraries.

IInd Step: High-level synthesis tool is used to optimize the generated code for the linear model of MPC.

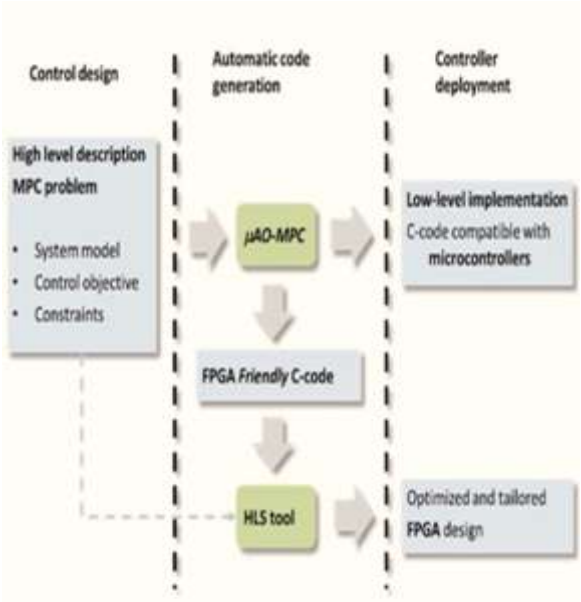

Fig 2: Flowchart for Field Programmable Gate Array based MPC using High Level Synthesis tool

For High Level Synthesis they use Vivado software suite which produce by Xilinx.

By these two steps method, they provide an easy and optimized solution of MPC design for Embedded system. For proofing it, they describe two examples first is based on Problem of simple DC motor and second is based on the problem of Chain of Masses.

Finally, the combined participation of High-Level Synthesis tool and FPGA technology is a good technique for MPC controllers with low cost, high performance, and energy efficient.

In [2] MPC is used for Robotic Visual Servoing System because Robot have many physical limitations regarding movement and visibility constraints.

General Visual Servoing Approach is given in Fig 3.

Typically, three types of Visual Servoing Controls are available

1) Position Based Visual Servoing
2) Image Based Visual Servoing
3) Hybrid Visual Servoing

In this paper, for controlling of Visual Servoing system of Robot which has 6-degree of freedom, they use an Image Based Visual Servoing system with Model Predictive Control methodology.

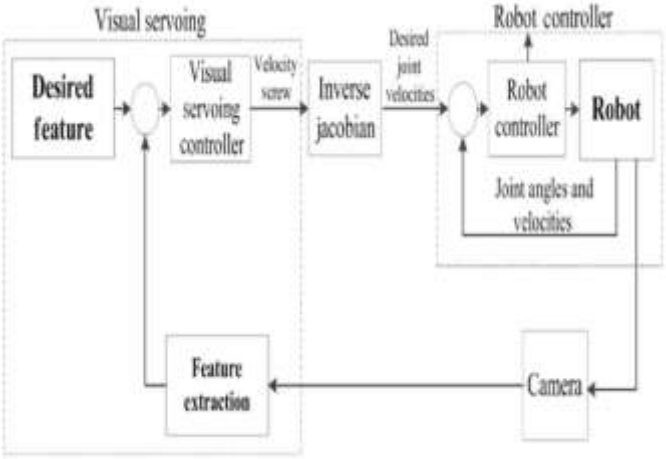

Fig 3. General Visual Servoing Approach

For implement a Model Predictive Control, they work on YALMIP toolbox for optimize the modeling of the Nonconvex and Convex problems. This tool box provides real time optimization, here sampling time is greater than computational time. After optimization, at every sampling time get the control signal. For Experiment they use VS-6556G Denso robot with a camera which is mounted on the end-effectors.

Final result of experiments is Model Predictive Control provide a good and effective Servoing system in place of general visual Servoing.

.In [3] Model Predictive Control system is used for autonomous ground vehicle control. Here it is used for path optimization process that's they call it model predictive path planning controller which means that it will avoid obstacles and an un-interrupted path following capability with optimized way.

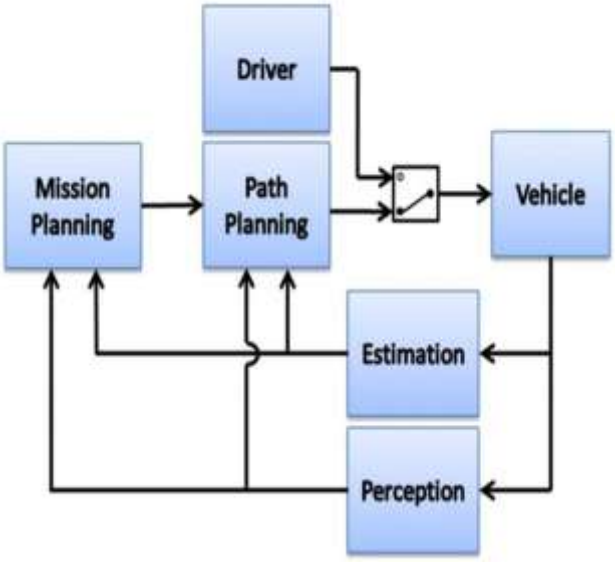

Fig 4. General block diagram of Autonomous Vehicle System

In path planning various factors works

(1) Vehicle Dynamics Model
(2) Potential Field
    a. Non-Crossable Obstacles
    b. Crossable Obstacle
    c. Road Lane Boundaries
(3) Path Planning

Model Predictive Path Planning Control need to solve these kinds of factors solution to run a vehicle flawlessly. For simulation, they use a Chevrolet Equinox model in CarSim software. Chevrolet Equinox model is used as Vehicle parameter in simulation software.

Finally, according to this paper MPC based Path planning and controlling is very effective that's why an autonomous ground vehicle is a success to run easily on the road with the various interrupt of the obstacle.

In [4] authors use MPC methodology to control air pressure and recirculation of Exhaust gasses in diesel engine air path. For controlling they declare various set points in the diesel engine like Variable Geometry Turbine, Exhaust gas recirculation throttle, Exhaust gas recirculation valve and Exhaust gas recirculation throttle ranges.

They do an experiment at Toyota Motor Co. and use dSPACE software for rapid prototyping. Simulation shows its capability of handle Manifold Absolut Pressure, Exhaust Pressure and turbocharger speed.

Finally, this paper shows MPC reduces the quantity of controller in the engine which are used in every set points of Engine.

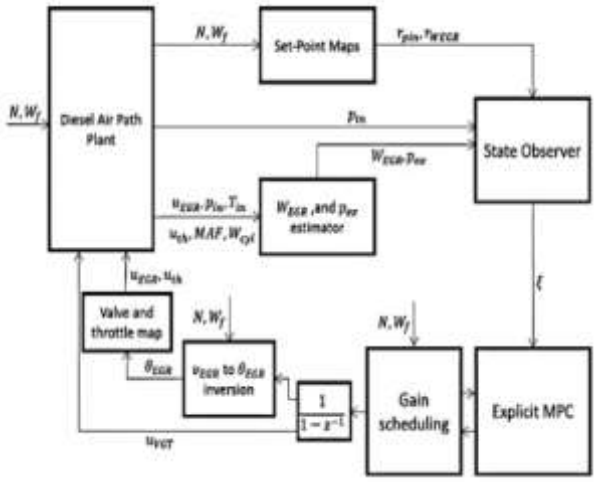

Fig 5. Control structure for MPC Based Diesel Engine Air Path

They define controller design in five number of section

(1) Rate Based Model Predictive control
(2) Gain Scheduling for Explicit MPC
(3) Rate-Based Model Predictive Control for Diesel Air Path
(4) Estimators
(5) Computational Complexity

In [5] for safe computation and Real Time Implementation FPGA is used as Model Predictive Controller.

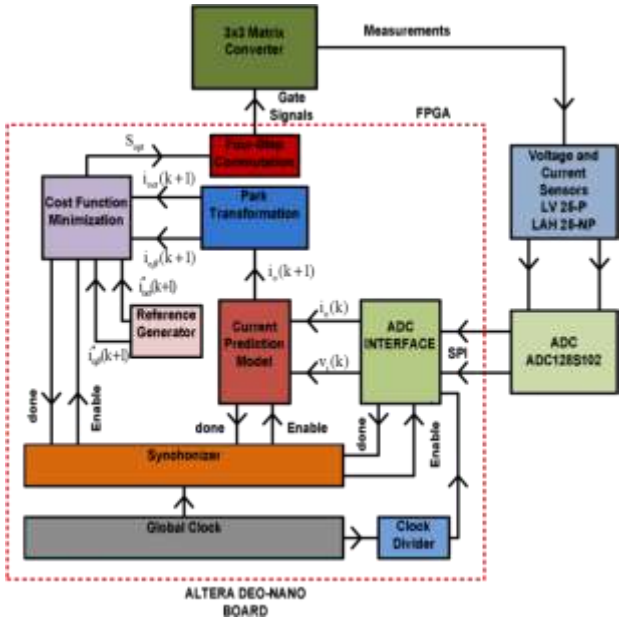

Fig 6. FPGA Based MPC Design For 3x3 DMC

For experiment they use 1.6 kW DMC prototype system, 16μs sampling Circuit, Clamp Circuit, Current Sensor Circuit, ADC and an IGBT. By the help FPGA they implement and use Four step of commutation strategy.

IV. CONCLUSION

After study and survey on various MPC architectures, it has been observed that the accuracy of the MPC is depended on the accuracy of model therefore special attention is required to design model for the targeted applications.Also, for the high performance high-speed controlling devices like FPGA, 32-bit controllers should be used in the design.

REFERENCES

[1]. Sergio lucia, Denisnevarro, Oscarlucia, Pablo Zometa, Ralph Findeisen "Optimized FPGA Implementation of Model Predictive Control for Embedded Systems Using High-Level Synthesis Tool " *IEEE Transactions ,2018.*

[2]. Amir Hajiloo, Mohammad Keshmiri, Wen-Fang Xie, and Ting-Ting Wang "Robust Online Model Predictive Control for a Constrained Image-Based Visual Servoing" *IEEE Transactions On Industrial Electronics,2016*

[3]. YadollahRasekhipour, Amir Khajepour, Shih-Ken Chen, and BakhtiarLitkouhi presented a paper "A Potential Field-Based Model Predictive Path-Planning Controller for Autonomous Road Vehicles"*IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS*,2016

[4]. Mike Huang, Kevin Zaseck, Ken Butts,IlyaKolmanovsky presented a paper on "Rate-Based Model Predictive Controller for Diesel Engine Air Path: Design and Experimental Evaluation", *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS,2015*

[5]. Ozan Gulbudak, Janosch Marquart and Enrico Santi presented a paper on "FPGA-Based Model Predictive Current Controller for 3x3 Direct Matrix Converter" *IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOLOGY,2014*