LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
API	Application Programming Interface
AGV	Automated Guided Vehicle
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CNC	Computer Numeric Control
DH	Denavit-Hartenberg
GUI	Graphical User Interface
HT	Homogeneous Transformation
IK	Inverse Kinematic
IFR	International Federation of Robotics
ISO	International Organisation for Standardization
JIT	just-in-time
NDT	Non-Destructive Testing
NP	Non-deterministic Polynomial
OBB	Oriented Bounding Box
PDE	Partial Differential Equation
RVC	Robotics Vision and Control
RIA	Robotic Industries Association
SQP	Sequential Quadratic Programming
STL	Stereolithography
3D	Three Dimensional
2D	Two Dimensional

LIST OF SYMBOLS

${}_{o}^{l}P$	location of a point *P* in the coordinate frame *l* relative to the origin frame *o*
${}_{o}^{l}P_x$	Projection of a point *P* in the coordinate frame *l* relative to the origin frame *o* on x axis
${}_{o}^{l}P_y$	Projection of a point *P* in the coordinate frame *l* relative to the origin frame *o* on y axis
${}_{o}^{l}P_z$	Projection of a point *P* in the coordinate frame *l* relative to the origin frame *o* on z axis
${}_{o}^{l}R$	orientation matrix
$\hat{x}_o, \hat{y}_o, \hat{z}_o$	basis vector of the coordinate frame *o*
$\hat{x}_l, \hat{y}_l, \hat{z}_l$	basis vector for the frame *l*
${}_{o}^{l}T$	Homogeneous transformation matrix
P	end-effector's position vector
R	end-effector's orientation matrix
∂_{fk}	nonlinear forward kinematics function
q	joint position vector
δ_k	fixed kinematic link parameters vector
a_i	link length
α_i	link twist
d_i	joint offset
θ_i	joint angle
${}_{i-1}T^{i}$	transformation matrix between any two joints of the robot
C	processing data required to select the feasible solution
X	desired configuration
$\mathbf{I}$	positive definite *n* x *n* generalized inertia matrix of the manipulator
τ	the *n* dimensional vectors of active forces
$\mathbf{w}^{\mathrm{W}}$	static wrench acts on the end-effector
$\boldsymbol{\delta}$	*n* dimensional vectors of dissipative generalized forces
$\ddot{\boldsymbol{\theta}}$	angular acceleration
$\mathrm{F}_{\mathbf{i}}$	force acting at the centre of mass of *i* th link
$\boldsymbol{m_i}$	mass of the *i* th link and $\dot{\boldsymbol{v}}_{\boldsymbol{i}}$ is the linear acceleration

$\dot{\boldsymbol{v}}_{\boldsymbol{i}}$	linear acceleration
τ	joint torque vector
$\mathbf{M}$	joint space symmetric inertia matrix
$\boldsymbol{G}$	gravity force vector
$\boldsymbol{h}$	vector of centrifugal and Coriolis forces
$\boldsymbol{q}$	joint position vector
$\dot{\boldsymbol{q}}$	joint velocity vector
$\ddot{\boldsymbol{q}}$	joint acceleration vector
$\boldsymbol{\mathcal{L}}$	Lagrange function
$\mathbf{K}$	total kinetic energy
$\mathbf{P}$	potential energy
m	mass of the system
v	velocity of system
$\mathbf{I}$	inertia
$\boldsymbol{\omega}$	angular velocity
g	magnitude of gravitational acceleration
l	link length
$\boldsymbol{\theta}$	rotation angle
$\boldsymbol{M}_{\boldsymbol{ij}}$	effective coupling inertia
$\boldsymbol{h}_{\boldsymbol{ijk}}$	centrifugal and Coriolis forces
$\boldsymbol{G}_{\boldsymbol{i}}$	gravitational repulsion force
p	number of nodes
H_{max}	maximum edge length
H_{min}	minimum edge length
p	number of nodal points
e	number of element edges
t	number of mesh element
d	distance error
N	n*umber of machines and job points*
n	degree-of-freedom of manipulator
α^j	orientation angle
$\boldsymbol{f}_{\boldsymbol{ij}}$	transportation cost
$\boldsymbol{c}_{\boldsymbol{ij}}$	material flow cost

$\boldsymbol{q^i}$	joint angle values of *i th* machine
$\boldsymbol{q^j}$	joint angle values of *j th* machine
$\vec{X}_j$	machine's job point vector
$\mathbf{N_{jj+1}}$	intercepts produced due to collision between point clouds of machines
$\mathbf{T_{jk}}$	intercepts produced due to collision between point clouds of machines and robot
${}_x^kR_{min}$	minimum value of the minimum bounding box along the x-axis of *k th* link of robot *R*
${}_x^kR_{max}$	maximum value of the minimum bounding box along the x-axis of *k th* link of robot *R*
$\mathbf{B_{jk}}$	intercepts produced due to collision between point clouds of two robots
M	number of robots
M1	Sand die conveyor
M2	Brusher1
M3	Dipping tank
M4	Oven conveyor
R1	Robot in Cell 1
R2	Robot in Cell 2