$$\frac{ml^2}{6}\begin{pmatrix}14 & 9 & c_{12} & 3 & c_{13}\\ 9 & c_{12} & 8 & 3 & c_{23}\\ 3 & c_{13} & 3 & c_{23} & 2\end{pmatrix}\begin{pmatrix}\ddot{\varphi}_1\\ \ddot{\varphi}_2\\ \ddot{\varphi}_3\end{pmatrix} + \frac{ml^2}{6}\begin{pmatrix}0 & 9 & s_{12} & & 3s_{13}\\ -9 & s_{12} & 0 & 3 & s_{23}\\ -3 & s_{13} & -3 & s_{23} & 0\end{pmatrix}\begin{pmatrix}\dot{\varphi}_1^2\\ \dot{\varphi}_2^2\\ \dot{\varphi}_3^2\end{pmatrix} + \frac{mgl}{2}\begin{pmatrix}5\cos\varphi_1\\ 3\cos\varphi_2\\ \cos\varphi_3\end{pmatrix} = \begin{pmatrix}1 & -1\\ 0 & 1\\ 0 & 0\end{pmatrix}\begin{pmatrix}\tau_1\\ \tau_2\end{pmatrix} + \begin{pmatrix}\lambda_1\\ \lambda_2\\ \lambda_3\end{pmatrix} \quad (190)$$

where, m and l denote the mass and length of the links, g is gravity acceleration, and for the sake of abbreviation it's taken $c_{ij} = \cos(\varphi_i - \varphi_j)$ and $s_{ij} = \sin(\varphi_i - \varphi_j)$. Similarly, in sub-motion M_2 the equations of motion are

$$ml^2\begin{pmatrix}20 & 15c_{12} & 9 & c_{13} & 3 & & c_{14}\\ 15 & c_{12} & 14 & 9 & c_{23} & 3 & c_{24}\\ 9 & c_{13} & 9 & c_{23} & 8 & 3 & c_{34}\\ 3 & c_{14} & 3 & c_{24} & 3 & c_{34} & 2\end{pmatrix}\begin{pmatrix}\ddot{\varphi}_1\\ \ddot{\varphi}_2\\ \ddot{\varphi}_3\\ \ddot{\varphi}_4\end{pmatrix} + \frac{ml^2}{6}\begin{pmatrix}0 & 15s_{12} & 9s_{13} & & & 3s_{14}\\ -15 & s_{12} & 0 & 9 & s_{23} & 3s_{24}\\ -9 & s_{13} & -9 & s_{23} & 0 & 3s_{34}\\ -3s_{14} & -3 & s_{24} & -3 & s_{34} & 0\end{pmatrix}\begin{pmatrix}\dot{\varphi}_1^2\\ \dot{\varphi}_2^2\\ \dot{\varphi}_3^2\\ \dot{\varphi}_4^2\end{pmatrix} (191)$$

$$+\frac{mgl}{2}\begin{pmatrix}7\cos\varphi_1 & 0 & & 0\\ 5 & & & \cos\varphi_2\\ 3\cos\varphi_3 & 0 & 1 & -1\\ \cos\varphi_4 & 0 & 0 & 1\\ 0 & 0 & & 0\end{pmatrix}\begin{pmatrix}\tau_1\\ \tau_2\\ \tau_3\end{pmatrix} + \begin{pmatrix}\lambda_2\\ \lambda_3\\ \lambda_4\end{pmatrix}R$$

Assuming a Coulomb friction model and using the Lagrange multiplier method, considering the stress equation, the normal component of the reaction, i.e. R, calculations can be performed from of the last row of the matrix form equation (191) given for the sub-motions M1 and M2 respectively, where we need to be replaced by:

$$\lambda_i = l_i(\cos\phi_i + \mu \operatorname{sgn}(v_{tip} \cdot \hat{\mathbf{x}})\sin\phi_i) \quad (192)$$

where, μ is the kinetic friction coefficient, and $\mathbf{v}_{tip}$ is the velocity vector of the tip of the last link in each sub-motion scuffing on the ground.

3. Conclusions

In the recent past, Automated Guided Vehicles (AGVs) have been the subject of a research effort to improve vehicle intelligence in different applications. Path tracking has been seen as a major challenge in autonomous mobile systems. Currently, some researchers are studying this problem under uncertain conditions such as dynamic obstacles and some known environments. This paper reviewed the different mathematical models for various AGV and service robots. Comparing the different AGV structures shows that the robot platform is mostly categorized based on its wheels or motion mechanism. To summarize, the AGV can be categorized as Differential type with Four, Six and Caterpillar, Independent's type, Ackerman, Legs and other structures as shown in figure (12). The following figure shows the types of service robots whose dynamic models are accumulated in this paper.

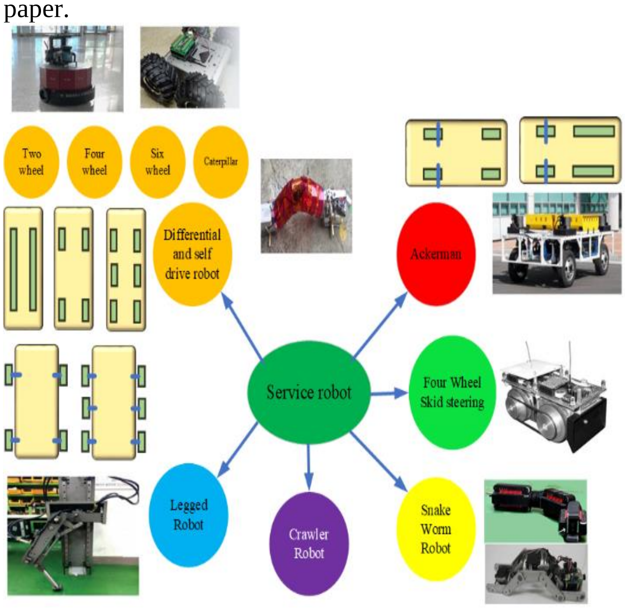

Figure 9. Types of service robot surveyed

based on the robots structures, the two Four- and six-wheel robots are typically used to carry higher payloads and / or to traverse rough terrain and they can offer good mobility. Compared to the four-wheel robot, the six-wheel robot has more redundancy in the event of wheel failure or loss. For the same tire size and vehicle mass, six wheels will exert less ground pressure than four wheels. However, six-wheeled vehicles of the same size may be heavier. Six wheels require more complex steering, drivetrain and suspension arrangements than four. To apply the same tractive force, the friction between the six-wheel drive and the ground is less than that of the four-wheel drive [42]. The applications of robotic could be extended on various potential works such as environmental, energy, hybrid materials, biomaterials, etc [43-52].

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