# The Multi-State Constraint Kalman Filter

Or, how we learned to stop worrying and love the null space

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*AER1513 Course Project*

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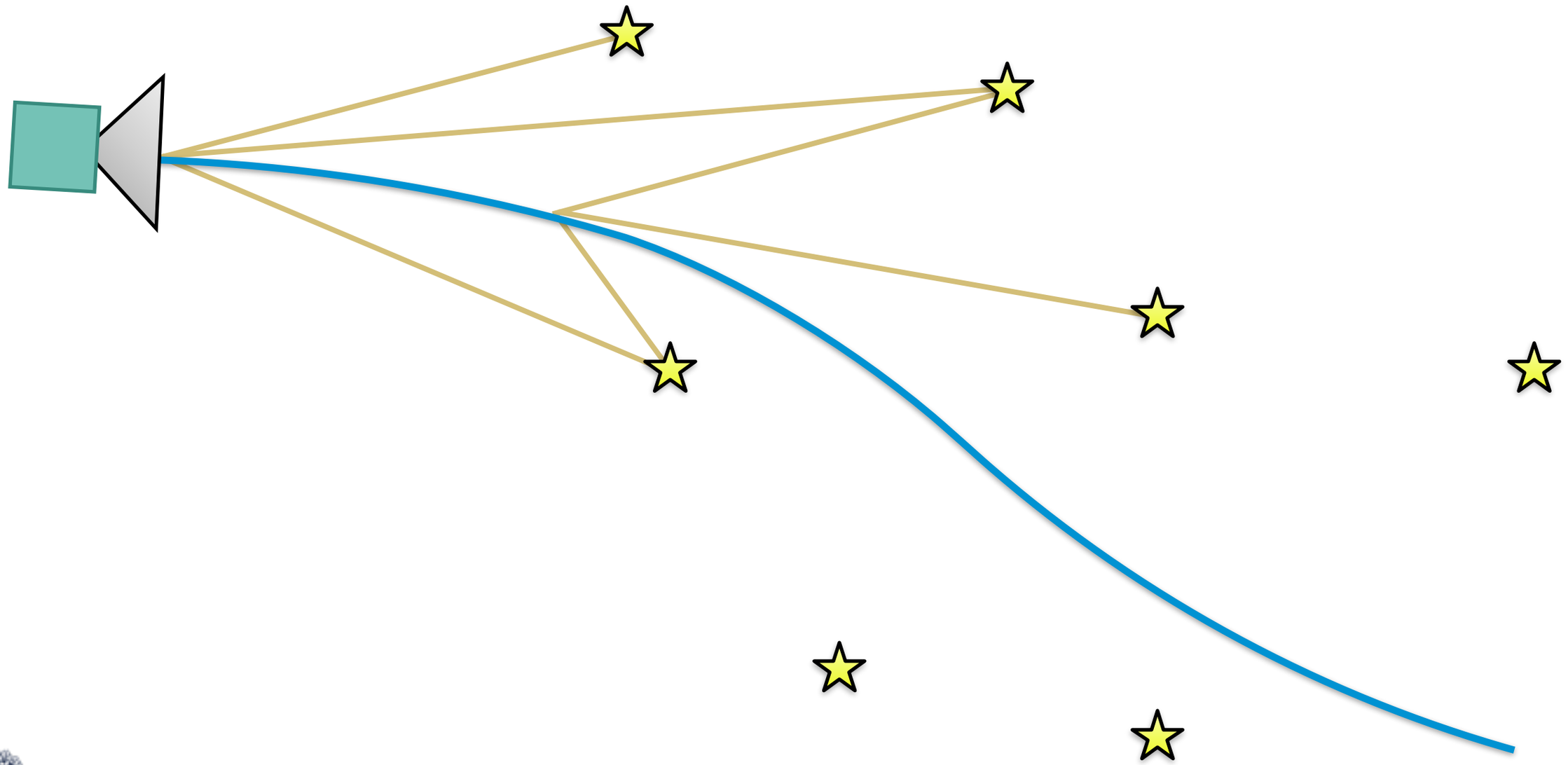
# **Problem:** Vision-aided Inertial Navigation

**Goal**: Use an IMU with a monocular camera to estimate motion *without a map*.



# **Algorithm:** MSCKF

**Idea**: Traditional pairwise landmark triangulation ignores correlations with observations at other states, so use a hybrid batch/recursive filter

**Batch component**: Track each feature until it goes out of view, then compute its position from *all available measurements*.

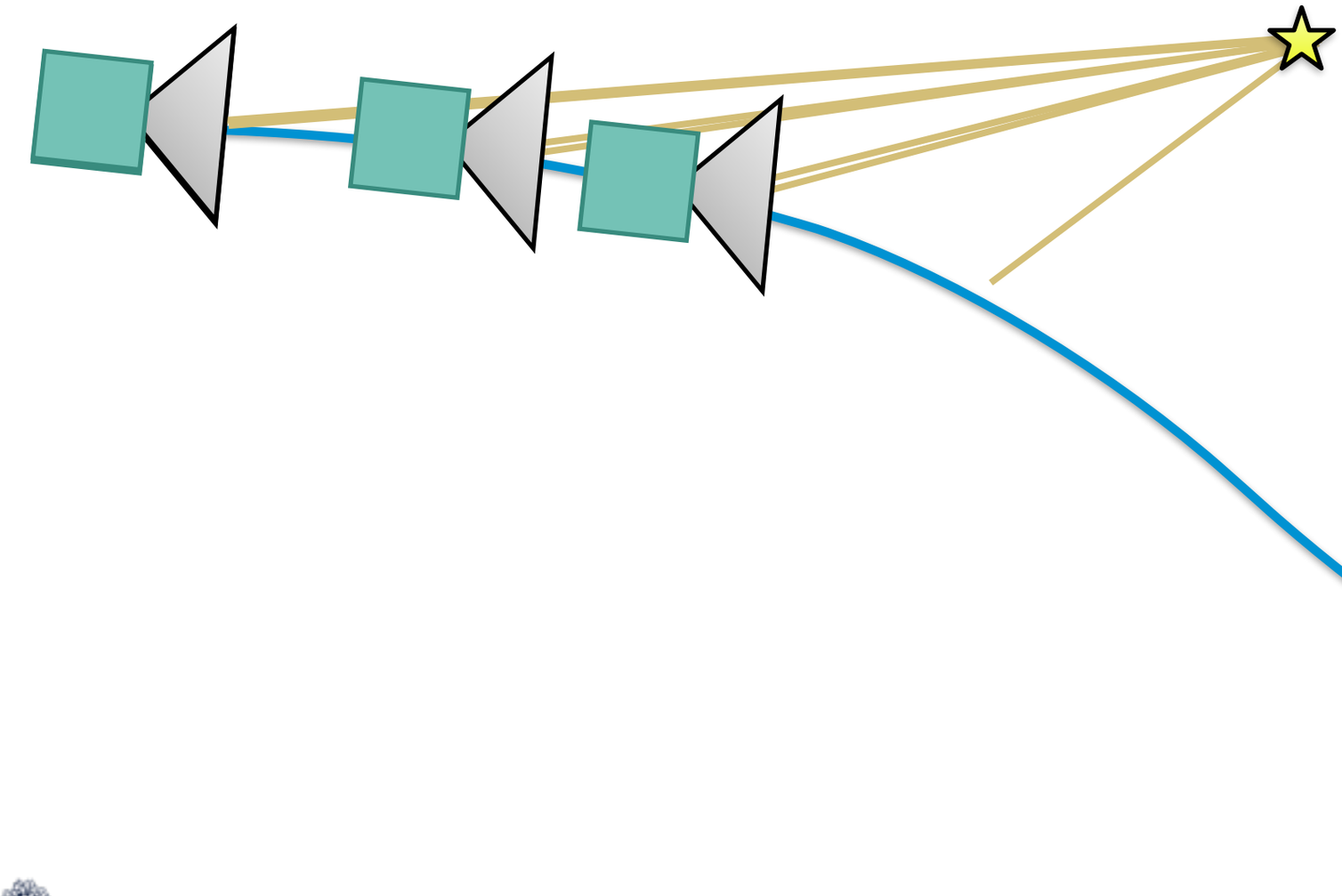
**Recursive component**: Use landmark position and all of its measurements (with null space trick) *to constrain motion*.

**Advantages over plain EKF**:

- **Sliding window of poses** allows each constraint to affect multiples states
- **Computational complexity is linear** in number of landmarks instead of cubic for plain EKF SLAM.

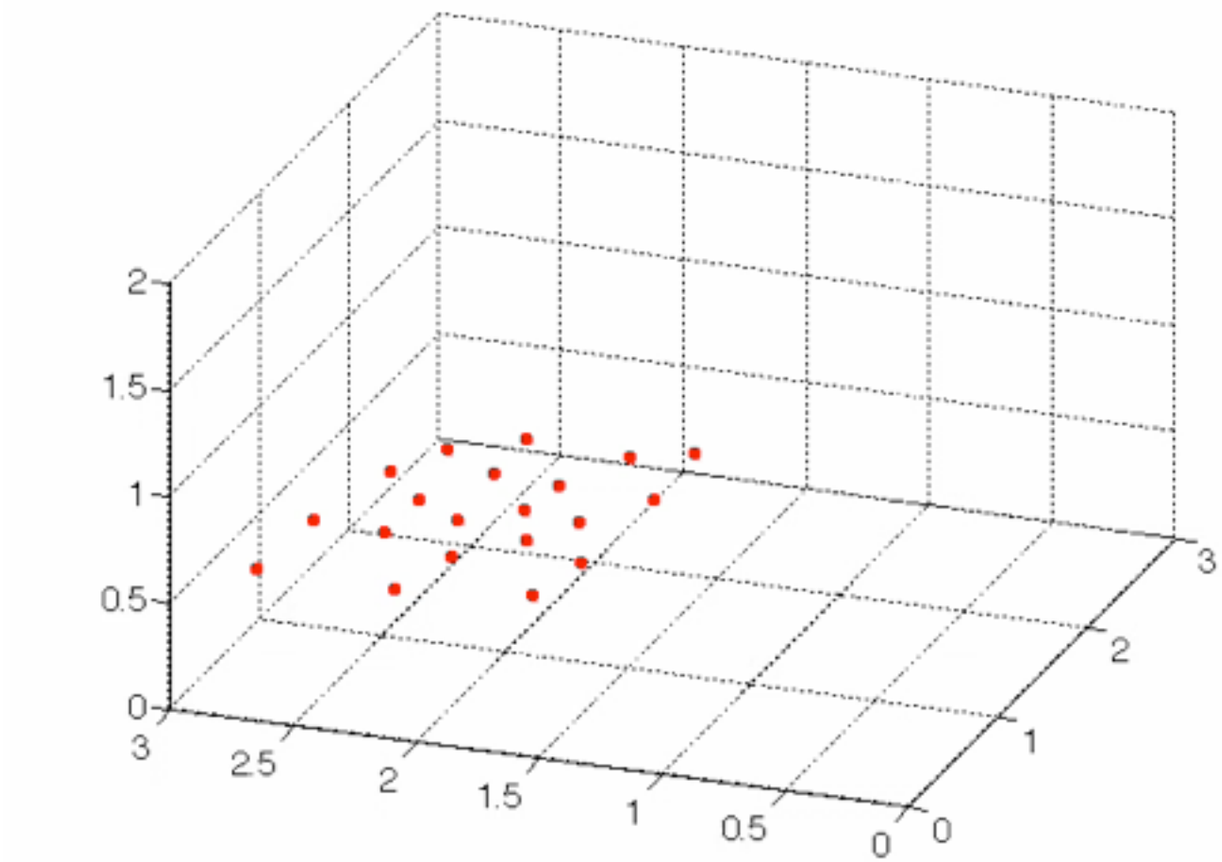
# **Algorithm:** MSCKF

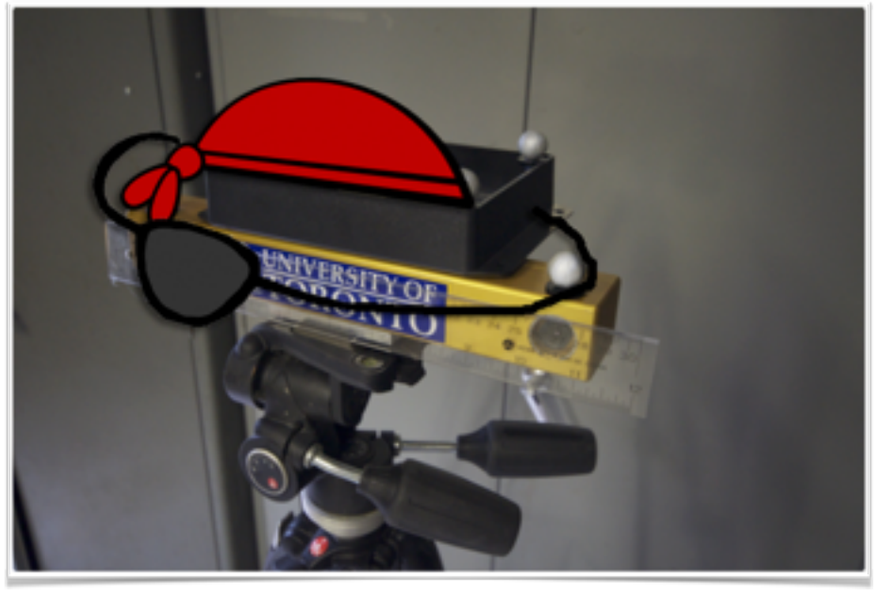
Each set of observations for a given feature (i.e. a ‘feature track’) adds a motion constraint.



1. Estimate feature position
2. Combine observations into exteroceptive update
3. Repeat for all feature tracks

# **Dataset:** Starry Night (Assignment 3)




- ☑ Perfect data association
- ☑ Ground truth for landmark positions
- ☑ Pre-integrated IMU measurements

# **Planned Analysis:** MSCKF

We will **investigate** MSCKF parameters:

1. Feature track length
2. Maximum window size

We will **compare**:

MSCKF *vs.* Sliding Window Batch Estimation


*State Estimation Street Fight*

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# Proof of Progress

augmentState.m
calcF.m
calcG.m
calcGNPosEst.m
calcHoj.m
calcJ.m
calcResidual.m
calcTH.m
dataset3.mat
MSCKF.m
MSCKF.m~
propagateImuState.m
propagateMsckfCovar.m
updateState.m

```
74
75          %============================STATE PROPAGATION=========
76
77          %Propagate state and covariance
78 -        msckfState = propagateMsckfCovar(msckfState, measurer
79
80          %Add camera pose to msckfState
81 -        msckfState = augmentState(msckfState, camera);
82
83
84          %============================FEATURE TRACKING==========
85          % Add observations to the feature tracks, or initiali
86          % If an observation is -1, add the track to featureTr
87 -        featureTracksToResidualize = {};
88 -        for featureId = 1:20
89 -            meas_k = measurements{state_k}.y(:, featureId);
90 -            if ismember(featureId, trackedFeatureIds)
91 -                if meas_k(1,1) == -1
92                      %Add to residualize queue and remove fron
93                      %struct
94 -                    featureTracksToResidualize{end+1} = featu
95 -                    featureTracks = featureTracks(trackedFeat
96 -                    trackedFeatureIds(trackedFeatureIds == fe
97 -                else
98                      %Append observation and increase k2
99 -                    featureTracks{trackedFeatureIds == featur
100 -                   featureTracks{trackedFeatureIds == featur
101 -               end
102 -           else
103                 %Track new feature
```

# Thanks!

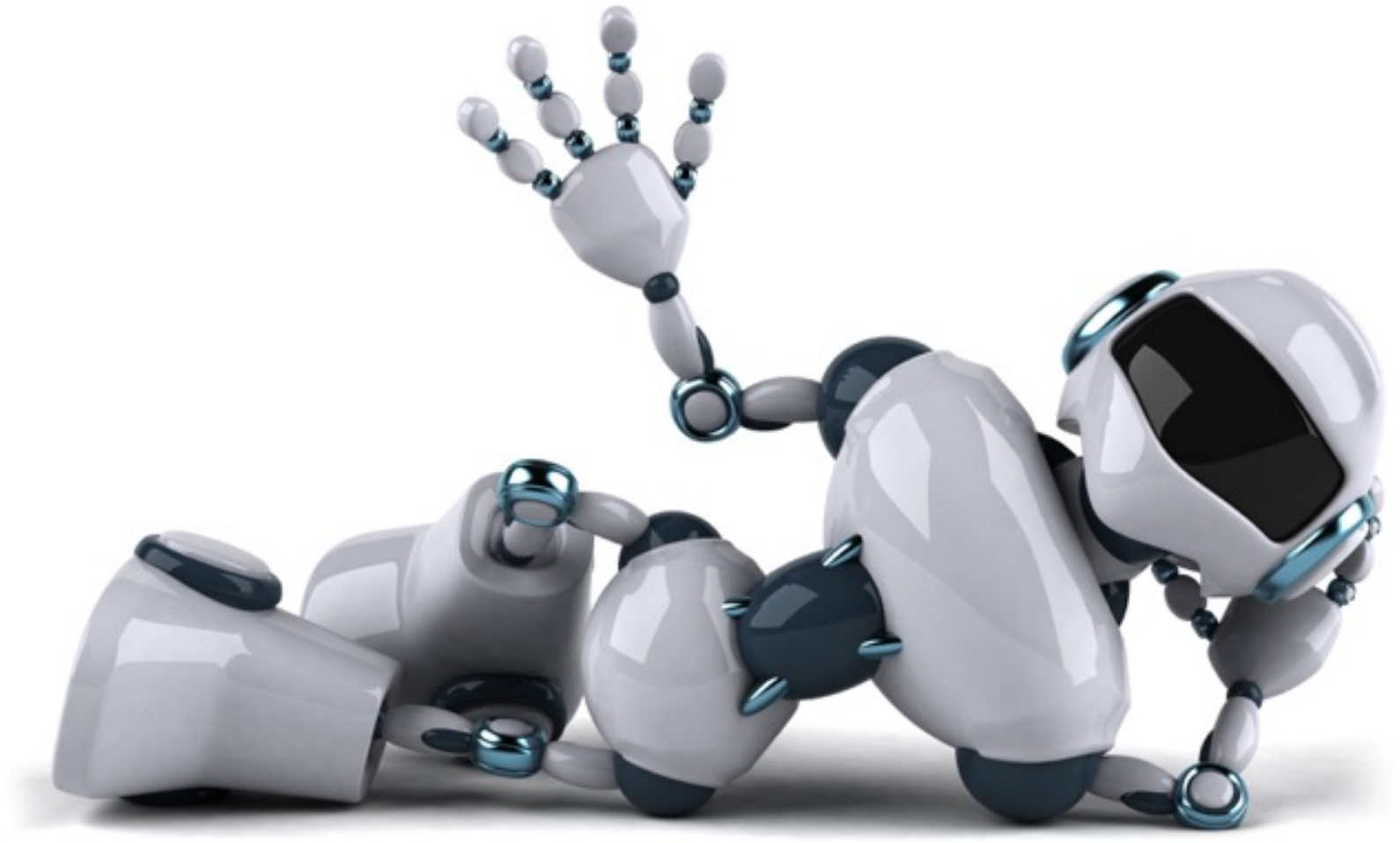

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Image credit: galleryhip.com