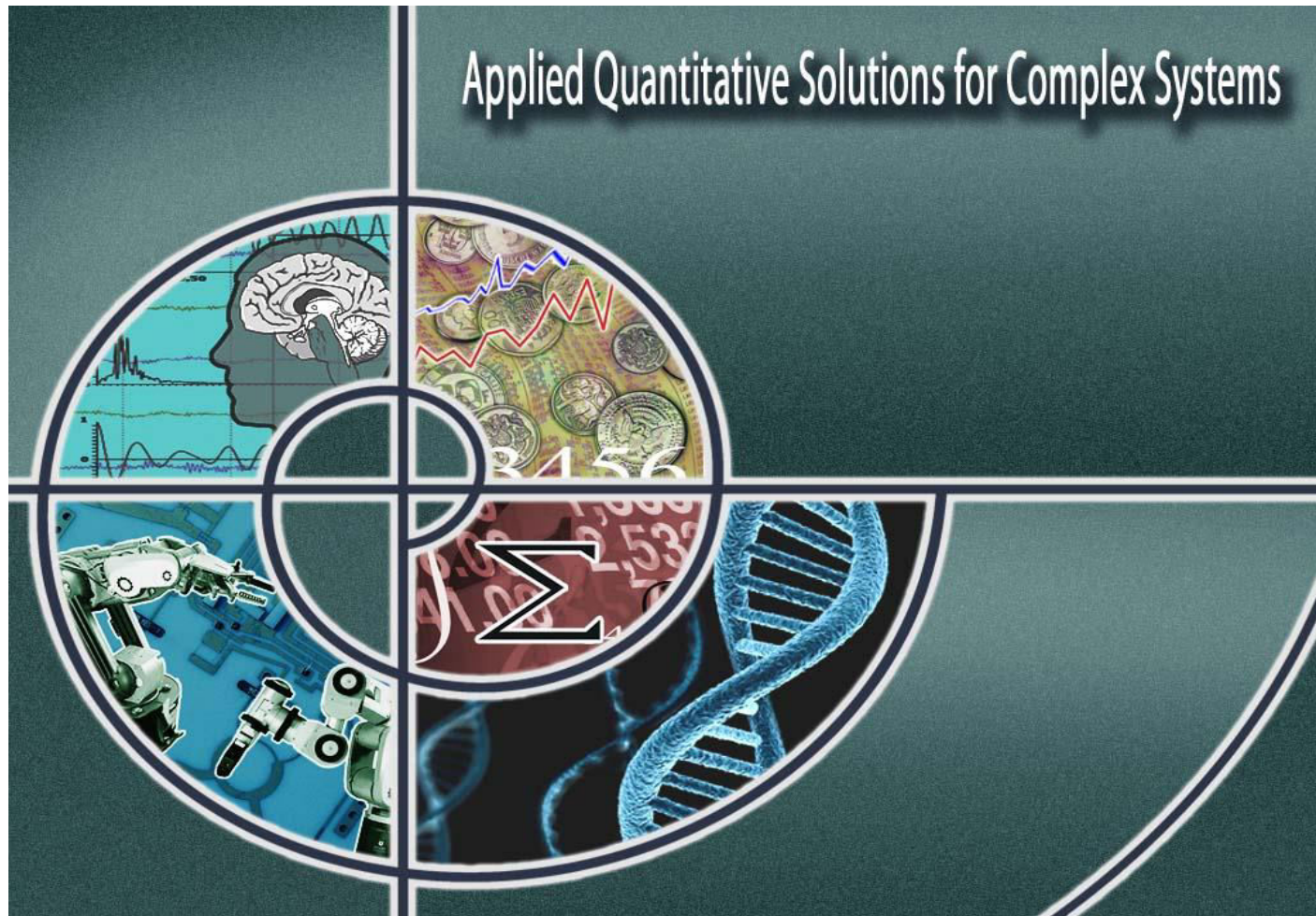


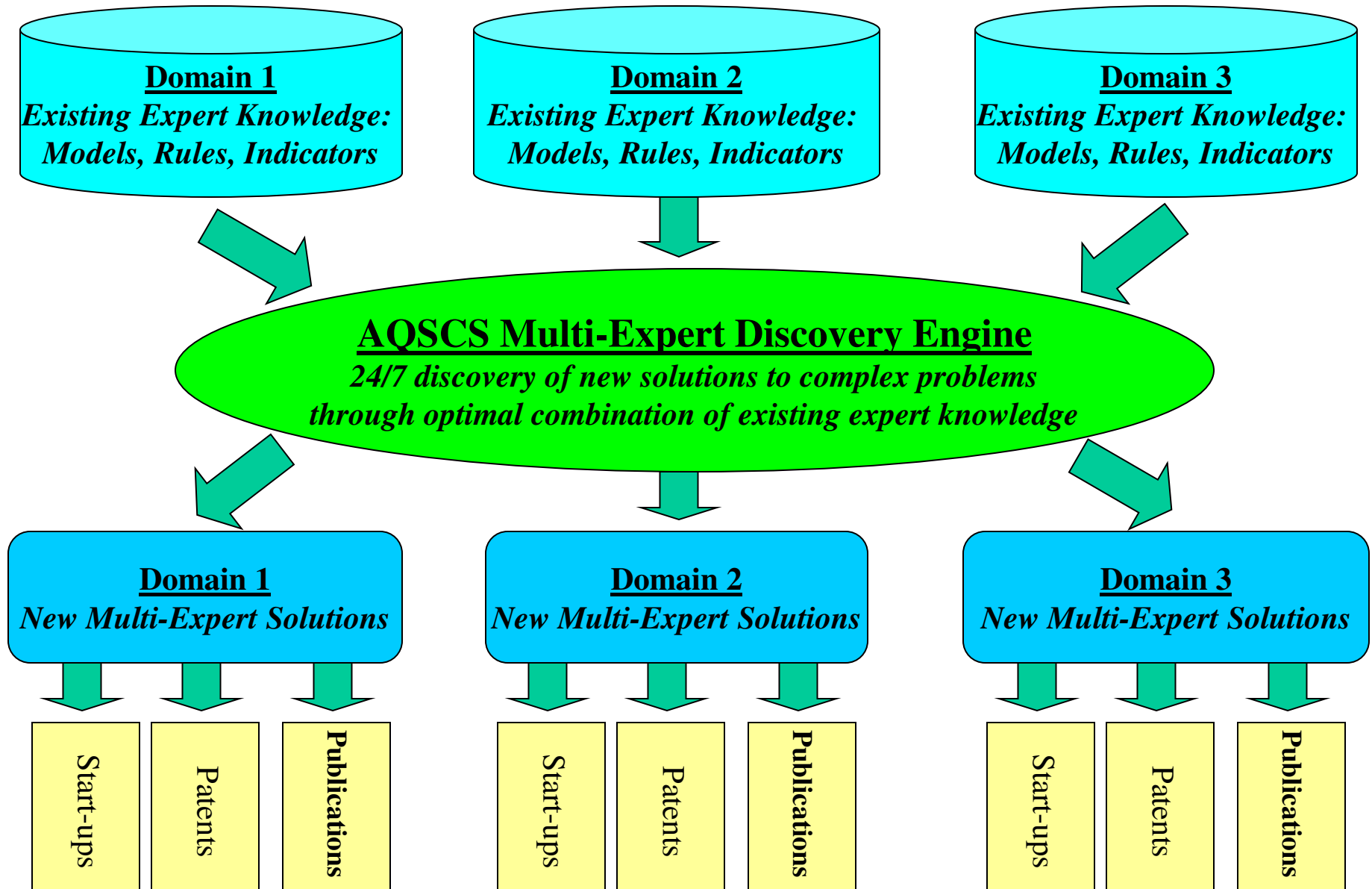
# *Discovery by Smart Combination*



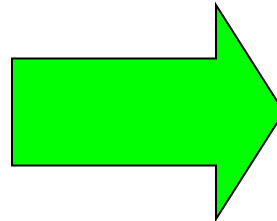
[www.aqscs.com](http://www.aqscs.com)

# AQSCS in Nutshell:

*incubator of cutting-edge solutions capitalizable through multiple start-ups and patents*



# Data is a Key for Competitive Edge and Success in Challenging Applications Lacking Universal Solutions



**Quantitative Finance & Business Intelligence**

**Professional Sport**

**Bioinformatics and Drug Discovery**

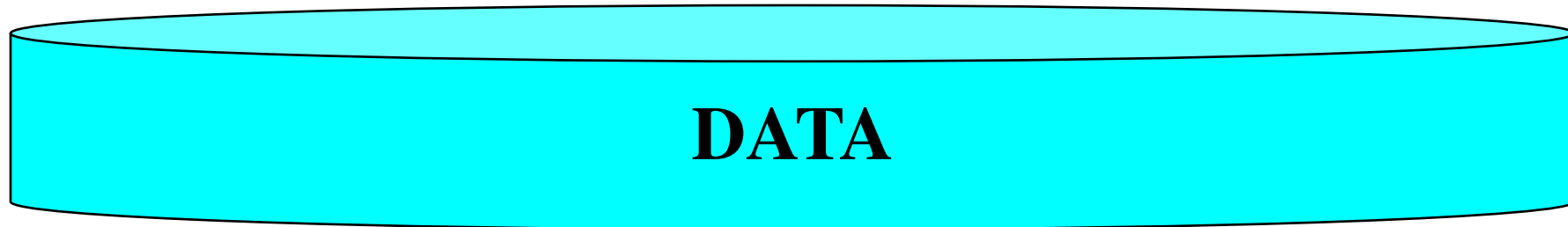
**Personalized Medicine**

**Computer Vision & Image Analysis**

**Quantitative Betting Strategies**

**Other Problems without Standard Solutions ...**

# Data-Driven Solutions - Advances and Challenges



## Collection

**Fast technological advances continuously expand possibilities of low-cost collection of high-resolution and multi-source data in biomedicine, business & finance, and in various fields of science and engineering.**

**In the foreseeable future, there are no critical fundamental obstacles that would prevent further advances in data collection technologies.**

## Compression

**Expanding technological abilities of collecting large amount of data creates challenges for data storage and transmission. Data compression algorithms become practically important in many data-intensive applications.**

**Challenges of further increase of compression ratio in “lossless” algorithms could be alleviated by decreasing costs and miniaturization of data storage and by increasing speed of data transmission.**

## Knowledge Extraction & Modeling

**Cutting-edge modern approaches include statistical and machine learning frameworks, universal fundamental models, as well as domain-specific analytical and other parsimonious models and rules from domain experts.**

**Knowledge extraction from data generated by complex systems and their modeling have several fundamental problems that cannot be easily resolved by advances in data collection capabilities.**

## **Complex Systems: Challenges of Modeling, Prediction, and Control**

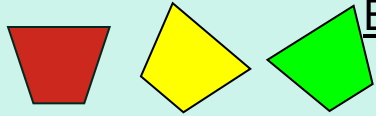
- Real-life complex systems are typically characterized by multi-scale and multi-regime dynamics with hard-to-predict regime changes.
- Observable spatio-temporal data from complex systems are complicated, noisy, and naturally incomplete due to practical inability to cover all possible regimes, scales, and dynamical patterns.
- These intrinsic properties of complex systems often prohibits creation of a universal global model, either analytical or data-driven, that is capable of covering multiple regimes with acceptable accuracy.
- In theory, universal data-driven models such as “black-box” machine learning algorithms (e.g., neural networks) are capable to create global approximation for a complex system. However, in practice, such approaches often lead to unstable solutions with very poor out-of-sample performance due to data incompleteness, noise, and non-stationarity.
- It is much easier to discover stable and simple models covering only a few particular regimes that cannot be used as global models. Therefore, many existing analytical/low-complexity models and other universal knowledge discovered by domain experts remain significantly underutilized due to their limited global performance.
- Multi-expert approaches such as simple model combination as well as variety of adaptive ensemble learning algorithms are widely accepted practical methodologies to compensate for limitations of individual models, strategies or rules.
- Majority of existing multi-expert techniques could only improve stability, i.e. reduce variance, without increasing accuracy of the model ensemble beyond the accuracy of the best individual model.
- Regime-switching multi-expert frameworks could dramatically improve accuracy of the model ensemble. However, in practice, such dynamic model-combination approach could become very unstable because of fundamental difficulty of the timely regime-change identification.
- Mainstream usage of ensemble learning involves combination of flexible "black-box" solutions (e.g., neural networks). However, in many challenging applications, the obtained "black-box" ensembles could be even less stable and much less interpretable than individual "black-box" models.

# AQSCS Multi-Expert Framework:

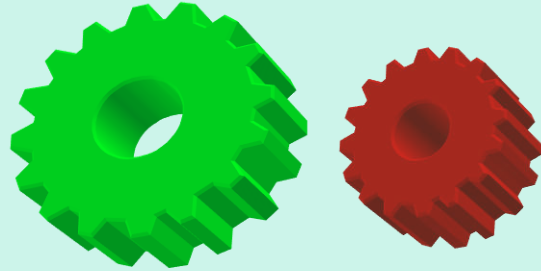
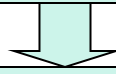
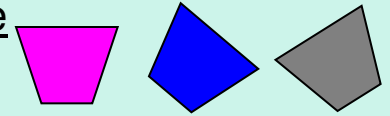
## *Fast Discovery of Cutting-Edge Solutions by Optimal Combination*

- Boosting-like ensemble learning is very distinct approach capable of simultaneous variance reduction and dramatic accuracy increase by optimal combination of complementary base models that are experts in their particular regimes.
- Unlike regime-switching approach, boosting-based solutions could be very stable since, by construction, each base model is not only an expert in its own regime but also demonstrate tolerable performance in all other regimes.
- AQSCS multi-expert discovery framework is based on state-of-the-art boosting-like algorithms with unique proprietary regularization techniques and objective functions that optimize and combine existing low-complexity models and other knowledge discovered by domain experts.
- Reliance on low-complexity base models formulated by domain experts, rather than on flexible "black-box" algorithms, effectively introduces domain-specific constraints in the optimization process that cannot be directly inferred from noisy and incomplete data. Such approach warrants discovery of universal multi-expert solutions with superior out-of-sample performance and stability.
- AQSCS discovery system effectively utilizes all existing complementary expert knowledge that is often remains unnoticed since majority of the mainstream approaches focus on the best single model.
- Success of AQSCS solutions supports intuitively obvious fact that it is much faster and more practical to build ensemble of simple models with outstanding global performance rather than spending years of research trying to discover (without any warranty of success) single universal model with acceptable global performance.

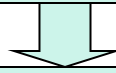
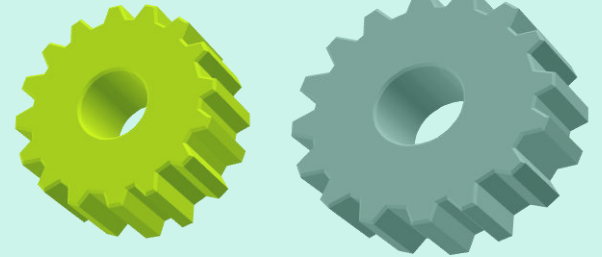
# AQSCS Generic Workflow for Each Domain: *Discovery Phase*



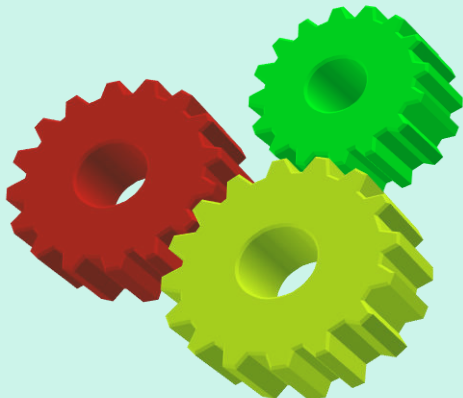
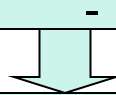
Base Indicators, Measures & other Expert Knowledge  
*from open publications, private communications  
with domain experts, and AQSCS own research*



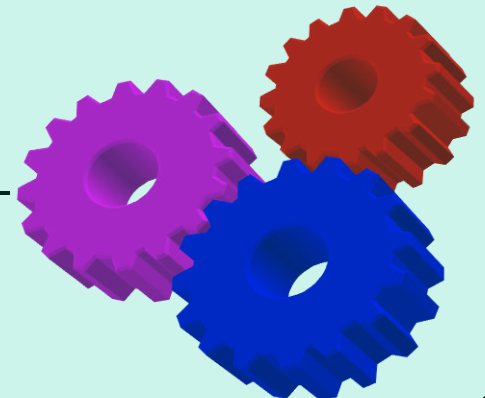
Base Models & Strategies  
*implemented & parametrized  
by AQSCS team*



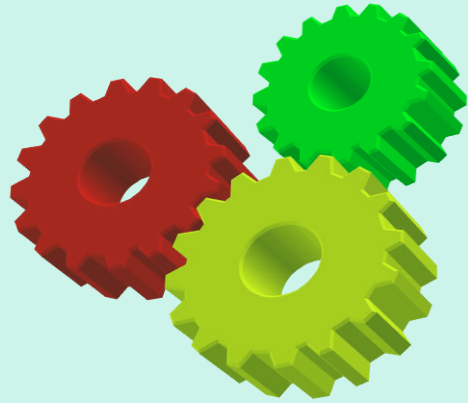
AQSCS Multi-Expert Discovery Engine  
*based on multi-objective boosting-based optimization proprietary framework*



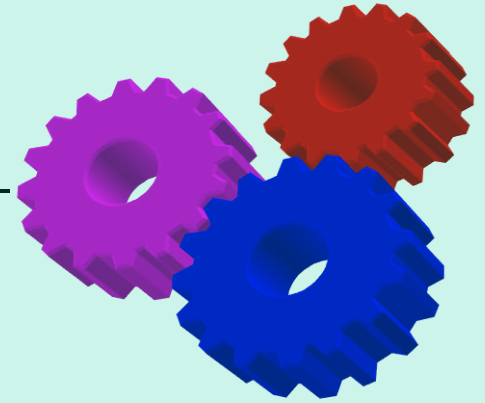
Generic Regime-Independent Ensembles  
of Complementary Models & Strategies



# AQSCS Generic Workflow for Each Domain: *Application Phase*



Generic Regime-Independent Ensembles  
of Complementary Models & Strategies

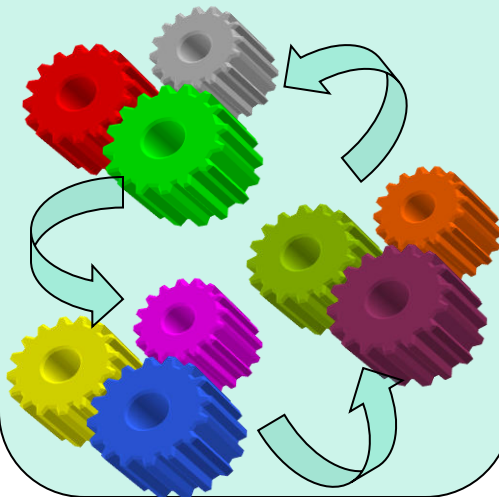


Direct Usage for Decision Making & Support  
*prediction, identification, and control*

Static Combination  
of Ensembles



Regime-Switching  
Rotation of Ensembles



Ensemble Decomposition Learning  
*technique pioneered by AQSCS*

Other Hard-to-Model  
Information  
Encoded in Ensembles

Multi-Dimensional State Vectors  
for Universal Quantitative Representation of  
Rare and Other Hard-to-Model States and  
Regimes of the Complex System



# AQSCS Multi-Expert Solutions for Complex Systems

generic multi-expert solutions discovery

multi-robot systems

business & finance

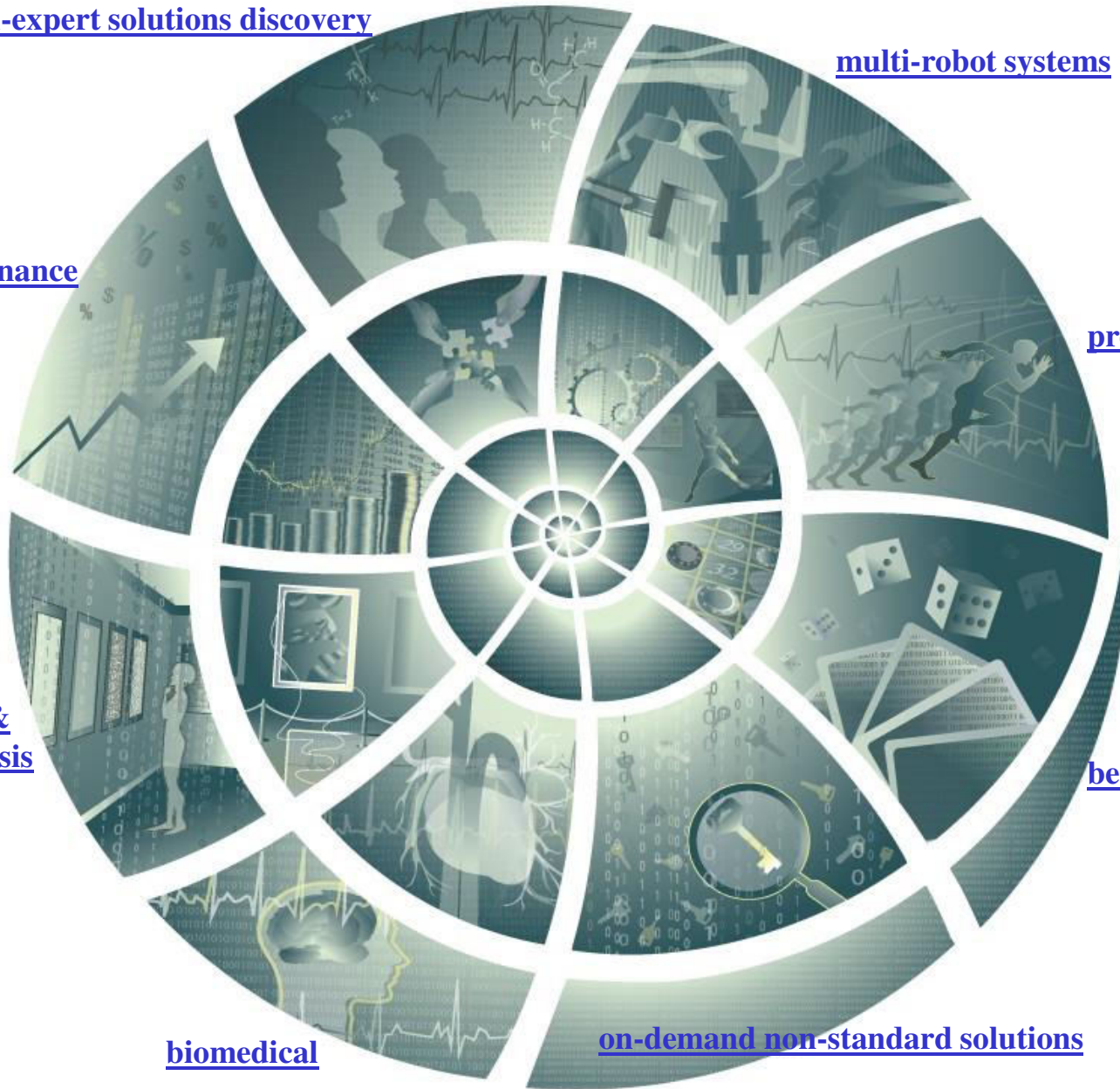
professional sport

visual arts & image analysis

betting strategies

biomedical

on-demand non-standard solutions



# Professional Sport

Multi-Complexity Measures & Other Multi-Expert Indicators Discovered by AQSCS Framework

Detailed Intra-Game Statistics & Similar Performance Data

Individual Technical Data Collected by Wearable Gadgets, Video Recording & Other Means During Training or Real Competitions

Physiological Data From Wearable Sport Gadgets & Smartphones  
*EKG, Gait & Other Time Series*

Multi-Expert Measures for Quantification & Predictive Monitoring of Technical Skills Level & Performance of Professional Athletes and Teams.

*Example:* Discovery of robust multi-feature metrics for skill-level quantification of individual golf players based on detailed shot patterns. The metrics can be used for optimization & personalization of the individual training process, monitoring & early prediction of changes in the player's performance, as well as for objective comparison of different players.

Early detection of overtraining and monitoring of rehabilitation progress

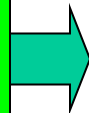
Quantitative Description and Monitoring of Individual Zones of Optimal Functioning (IZOF)

Monitoring and early detection of emerging life-threatening abnormalities in athletes

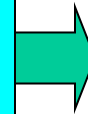
Integrated Decision Support Solutions for Athletes and Coaches

# Business & Finance

Regime-Independent  
Portfolios of  
Trading Strategies  
&  
Multi-Expert  
Market Indicators  
Discovered by  
AQSCS Framework



Multi-scale  
Market and Business  
Data



*Regime-Independent Multi-Expert Systems for  
Medium-Frequency Intraday Systematic Trading*

*Complexity and Distance Measures of Intraday  
Multi-Strategy Positions as Early Predictors of  
Market Regime Changes*

*Intraday Multi-Strategy Position State Vectors as  
Universal Detectors of Rare, Emerging, and  
Hard-to-Analyze Tradable Events*

*Business Intelligence Indicators for Early  
Prediction of Regime Changes and Detection of  
Rare, Emerging, and Hard-to-Analyze Events*

# Biomedical

Multi-Complexity &  
other Multi-Expert  
Ensemble Measures  
Discovered by  
AQSCS Framework

Physiological Data From  
Clinical Equipment &  
Wearable Gadgets  
*EKG, EEG, EMG &  
Gait Time series*

Bioinformatics Data  
*DNA sequences etc.*

Medical Images

Other Biomedical Data

*Preventive Express Diagnostics of Complex, Asymptomatic,  
and Life-Threatening Abnormalities*

*Universal Indicators for Robust Detection of Multiple  
Abnormalities*

*Robust Detection of Emerging and Transient Abnormalities*

*Real-Time Prediction of Acute and Critical Events*

*Rare Psycho-Physiological States and Pathologies:  
Robust Detection and Quantitative Description*

*Robust Quantitative Monitoring in Personal Wellness and  
Personalized Medicine Applications*

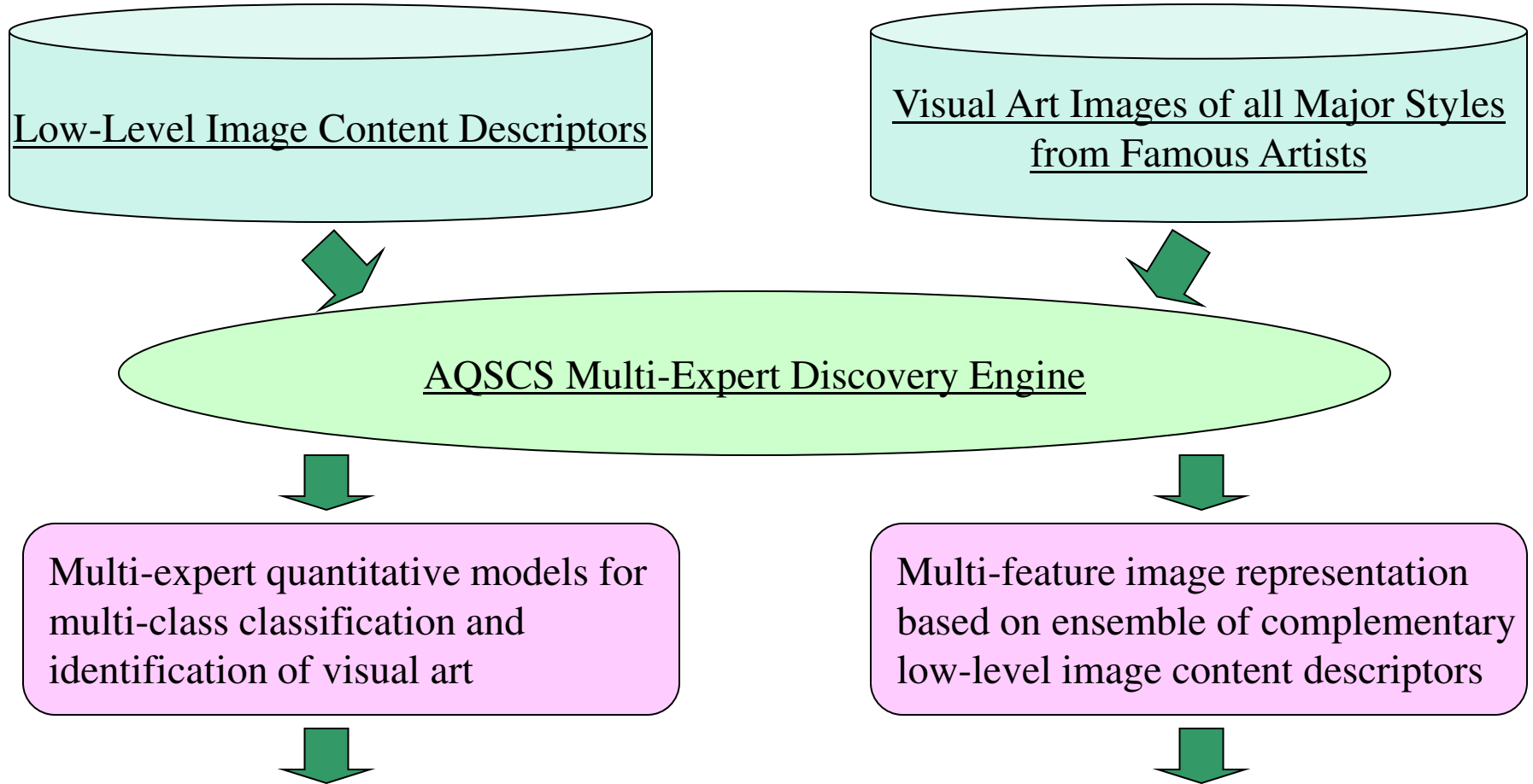
*Diagnostics and Monitoring of Neuro-Degenerative Diseases  
from Gait Dynamics*

*Remote Biometrics Based on Gait Dynamics*

*Multi-Complexity Analysis in Bioinformatics Applications  
and Drug Discovery*

*Multi-Complexity Spatial Analysis of Medical Images*

# Analysis of Visual Arts and Generic Category Image Recognition



## Applications

- Automated identification of visual art by analysis of hard-to-detect multi-scale spatial features.
- Early detection of potentially talented artists for investment purposes.
- Quantitative detection of style changes or improvement during artist education and development.
- Quantitative comparison of any visual-art pieces using unique multi-feature image representation.

# Betting Strategies Applications

**AQSCS Multi-Complexity  
and other Multi-Expert  
Measures for Prediction  
& Quantification of Rare  
and Hard-to-Analyze  
Events and Patterns**

**Historical Sports Data**  
*Detailed Intra-Game Statistics  
for Different Teams and  
Individual Players*

Maximization of Betting Profit  
by Early Prediction of Regime  
Changes in the Performance of  
Teams and Individual Players

Generic ensembles of  
complementary betting  
strategies with optimal  
risk/profit profiles

**Historical Data from  
Games with Significant  
Behavioral and Psychological  
Components (e.g., Poker)**

Multi-Feature Behavioral State  
Quantification for Identification  
of Different Psychological  
Game Modes of the Players  
Including Bluff Detection

# Additional Information

- Further details about AQSCS multi-expert framework, application examples, future developments, and other information are available at [www.aqscs.com](http://www.aqscs.com)
- Many core ideas of AQSCS multi-expert framework and its novel multi-disciplinary applications have been pioneered by AQSCS research team and are published in mainstream journals and conference proceedings. Critical proprietary details of the AQSCS algorithms are not disclosed in the open publication sources. Publication links and selected preprints are available at <http://www.aqscs.com/index-3.html>
- Further details of the AQSCS unique solutions for challenging problems of modeling, prediction, and control of a wide range of complex systems are available at <http://www.aqscs.com/index-2.html>
- Please contact us at [info@aqscs.com](mailto:info@aqscs.com)