Type IV pili (TFP) are long and thin filaments that extend from the surface of many bacteria. In *Pseudomonas aeruginosa*, successive TFP extension, attachment and retraction power twitching motility and regulate virulence and biofilm formation. Three motor components actuate TFP movements so that extensions and retractions drive surface motility. At the molecular level, rapid polymerization of the pilin subunits PilA by the extension motor PilB promotes TFP assembly and growth, while the retraction motors PilT and PilU rapidly depolymerize PilA back into the periplasm. Whether these motors sequentially coordinate their activity remains unclear. Here, we show that *P. aeruginosa* orchestrate TFP motorized activity to power efficient surface motility and activate virulence. To do this, we dynamically visualized TFP extension, attachment and retraction events at high resolution in four dimensions using label-free interferometric scattering microscopy. By precisely timing successive attachment, retraction and detachment, we show that *P. aeruginosa* engages motors very rapidly after TFP encounter the surface. TFP only rarely retracted without attaching, indicating that retraction motors could engage upon sensing contact with a solid substrate. We also found that *P. aeruginosa* successively recruits its two motors: a first motor is activated to generate tension in the fiber upon pilus contact with the surface, then the second motor is activated to drive cell displacement. Finally, we found that the force generated in the pilus fiber during retraction improved the attachment strength of the same pilus to the surface, increasing effective residence time during retraction and improving adhesion. Altogether, we found that *P. aeruginosa* sequentially controls extension, attachment, retraction to efficiently generate periodic activity, thereby efficiently driving displacements on surfaces.